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REPORT

OF THE

EIGHTY-FIFTH MEETING OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE



MANCHESTER: 1915

SEPTEMBER 7 – 11

LONDON
JOHN MURRAY, ALBEMARLE STREET
1916

Office of the Association Burlington House, London, W.

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RULES OF
THE BRITISH ASSOCIATION.

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

Chapter I.

Objects and Constitution.

Objects.

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.

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

Constitution.

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

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.

Annual Meetings.

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.

Chapter II.

The General Committee.

Constitution.

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

(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.

Constitution.

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

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.

Functions.

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.

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.

Procedure

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.

* Amended by the General Committee at Winnipeg, 1909, and Manchester, 1915.

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 return the balance of the grant, if any, which remains unexpended ; provided that a Research Committee may, in the first year of its appointment only, apply for leave to retain an unexpended balance when or before its Report is presented, due reason being given for such application.*

(*d*) Additional Grant.

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.

* Amended by the General Committee at Dundee, 1912.

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.

Elections.

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

(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.

The President.

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 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.

General Officers.

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

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.

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

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

Investments. 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.

Cheques. 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.

Chapter VIII.

The Annual Meetings.

Local Officers and Committees. 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.

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.

Functions. 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.

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.

Condition 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 President,* Vice-President,* 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.

* Amended by the General Committee at Manchester, 1915.

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.

TRUSTEES, GENERAL OFFICERS, &c., 1831–1915.

TRUSTEES.

1832–70 (Sir) R. I. MURCHISON (Bart.), F.R.S.
1832–62 JOHN TAYLOR, Esq., F.R.S.
1832–39 C. BABBAGE, Esq., F.R.S.
1839–44 F. BAILY, Esq., F.R.S.
1844–58 Rev. G. PEACOCK, F.R.S.
1858–82 General E. SABINE, F.R.S.
1862–81 Sir P. EGERTON, Bart., F.R.S.
1872–1913 Sir J. LUBBOCK, Bart. (afterwards Lord AVEBURY), F.R.S.
1881–83 W. SPOTTISWOODE, Esq., Pres.R.S.
1883– Lord RAYLEIGH, F.R.S.
1883–98 Sir LYON (afterwards Lord) PLAYFAIR, F.R.S.
1898–1915 Prof. (Sir) A. W. RÜCKER, F.R.S.
1913– Major P. A. MACMAHON, F.R.S.
1915– Dr. G. CAREY FOSTER, F.R.S.

GENERAL TREASURERS.

1831 JONATHAN GRAY, Esq.
1832–62 JOHN TAYLOR, Esq., F.R.S.
1862–74 W. SPOTTISWOODE, Esq., F.R.S.
1874–91 Prof. A. W. WILLIAMSON, F.R.S.
1891–98 Prof. (Sir) A. W. RÜCKER, F.R.S.
1898–1904 Prof. G. C. FOSTER, F.R.S.
1904– Prof. JOHN PERRY, F.R.S.

GENERAL SECRETARIES.

1832–35 Rev. W. VERNON HARCOURT, F.R.S.
1835–36 Rev. W. VERNON HARCOURT, F.R.S., and F. BAILY, Esq., F.R.S.
1836–37 Rev. W. VERNON HARCOURT, F.R.S., and R. I. MURCHISON, Esq., F.R.S.
1837–39 R. I. MURCHISON, Esq., F.R.S., and Rev. G. PEACOCK, F.R.S.
1839–45 Sir R. I. MURCHISON, F.R.S., and Major E. SABINE, F.R.S.
1845–50 Lieut.-Colonel E. SABINE, F.R.S.
1850–52 General E. SABINE, F.R.S., and J. F. ROYLE, Esq., F.R.S.
1852–53 J. F. ROYLE, Esq., F.R.S.
1853–59 General E. SABINE, F.R.S.
1859–61 Prof. R. WALKER, F.R.S.
1861–62 W. HOPKINS, Esq., F.R.S.
1862–63 W. HOPKINS, Esq., F.R.S., and Prof. J. PHILLIPS, F.R.S.
1863–65 W. HOPKINS, Esq., F.R.S., and F. GALTON, Esq., F.R.S.
1865–66 F. GALTON, Esq., F.R.S.
1866–68 F. GALTON, Esq., F.R.S., and Dr. T. A. HIRST, F.R.S.
1868–71 Dr. T. A. HIRST, F.R.S., and Dr. T. THOMSON, F.R.S.
1871–72 Dr. T. THOMSON, F.R.S., and Capt. DOUGLAS GALTON, F.R.S.
1872–76 Capt. D. GALTON, F.R.S., and Dr. MICHAEL FOSTER, F.R.S.
1876–81 Capt. D. GALTON, F.R.S., and Dr. P. L. SCLATER, F.R.S.
1881–82 Capt. D. GALTON, F.R.S., and Prof. F. M. BALFOUR, F.R.S.
1882–83 Capt. DOUGLAS GALTON, F.R.S.
1883–95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895–97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHAFER, 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.
1903–13 Major P. A. MACMAHON, F.R.S., and Prof. W. A. HERDMAN, F.R.S.
1913– Prof. W. A. HERDMAN, F.R.S., and Prof. H. H. TURNER, F.R.S.

ASSISTANT GENERAL SECRETARIES, &c.: 1831–1904.

1831 JOHN PHILLIPS, Esq., *Secretary.*
1832 Prof. J. D. FORBES, *Acting Secretary.*
1832–62 Prof. JOHN PHILLIPS, F.R.S.
1862–78 G. GRIFFITH, Esq., M.A.
1881 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1881–85 Prof. T. G. BONNEY, F.R.S., *Secretary.*
1885–90 A. T. ATCHISON, Esq., M.A., *Secretary.*
1890 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1890–1902 G. GRIFFITH, Esq., M.A.
1902–04 J. G. GARSON, Esq., M.D.

ASSISTANT SECRETARIES.

1878–80 J. E. H. GORDON, Esq., B.A.
1904–09 A. SILVA WHITE, Esq.
1909– O. J. R. HOWARTH, Esq., M.A.

Presidents and Secretaries of the Sections of the Association, 1901–1914.

(The List of Sectional Officers for 1915 will be found on p. li.)

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
SECTION A.[1]—MATHEMATICS AND PHYSICS.		
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 (*Rec.*), 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 (*Rec.*), 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 (*Rec.*), 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 (*Rec.*), 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 (*Rec.*).
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 (*Rec.*), 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 (*Rec.*).
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 (*Rec.*), Prof. E. T. Whittaker.
1909. Winnipeg	Prof. E. Rutherford, F.R.S....	Prof. F. Allen, Prof. J. C. Fields, E. Gold, F. Horton, Prof. A. W. Porter (*Rec.*), Dr. A. A. Rambaut.
1910. Sheffield ...	Prof. E. W. Hobson, F.R.S....	H. Bateman, A. S. Eddington, E. Gold, Dr. F. Horton, Dr. S. R. Milner, Prof. A. W. Porter (*Rec.*).
1911. Portsmouth	Prof. H H. Turner, F.R.S. ...	H. Bateman, Prof. P. V. Bevan, A. S. Eddington, E. Gold, Prof. A. W. Porter (*Rec.*), P. A. Yapp.
1912. Dundee ...	Prof. H. L. Callendar, F.R.S.	Prof. P. V. Bevan, E. Gold, Dr. H. B Heywood, R. Norrie, Prof. A. W. Porter (*Rec.*), W. G. Robson, F. J. M. Stratton.
1913. Birmingham	Dr. H. F. Baker, F.R.S.	Prof. P. V. Bevan (*Rec.*), Prof. A. S. Eddington, E. Gold, Dr. H. B. Heywood, Dr. A. O. Rankine, Dr. G. A. Shakespear.
1914. Australia..	Prof. F. T. Trouton, F R.S....	Prof. A. S. Eddington (*Rec.*), E. Gold, Prof. T. R. Lyle, F.R.S., Prof. S. B. McLaren, Prof. J. A. Pollock, Dr. A. O. Rankine.

[1] Section A was constituted under this title in 1835, when the sectional division was introduced. The previous division was into 'Committees of Sciences.'

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
SECTION B.[2]—CHEMISTRY.		
1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose (*Rec.*).
1902. Belfast.....	Prof. E. Divers, F.R.S.....	R. F. Blake, M. O. Forster, Prof. G. G. Henderson, Prof. W. J. Pope (*Rec.*).
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 (*Rec.*).
1904. Cambridge	Prof Sydney Young, F R.S.	Dr. M. O. Forster, Prof. G. G. Henderson, Dr. H. O. Jones, Prof. W. J. Pope (*Rec.*).
1905. SouthAfrica	George T. Beilby	W. A. Caldecott, Mr. M. O. Forster, Prof. G. G. Henderson (*Rec.*), 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 (*Rec*).
1907. Leicester...	Prof. A Smithells, F.R.S. ..	Dr. E. F. Armstrong, Prof. A. W. Crossley (*Rec*), J. H. Hawthorn, Dr. F. M. Perkin.
1908. Dublin	Prof. F. S. Kipping, F R.S. ...	Dr. E. F. Armstrong (*Rec.*), Dr. A. McKenzie, Dr. F. M. Perkin, Dr. J H. Pollock.
1909. Winnipeg...	Prof. H. E. Armstrong, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. T. M. Lowry, Dr. F. M. Perkin, J. W. Shipley.
1910. Sheffield ...	J E Stead, F R S.	Dr. E. F. Armstrong (*Rec.*), Dr. T. M. Lowry, Dr. F. M. Perkin, W. E. S. Turner.
	Sub-section of Agriculture— A D. Hall, F.R.S.	Dr. C. Crowther, J. Golding, Dr. E. J. Russell.
1911. Portsmouth	Prof. J. Walker, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. T. M. Lowry, Dr. F. Beddow.
1912. Dundee ...	Prof. A. Senier, M.D.	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. A. Holt, Dr. J. K. Wood.
1913. Birmingham	Prof W. P. Wynne, F R S....	Dr. E F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. A. Holt, Dr. H. McCombie.
1914. Australia...	Prof. W. J. Pope, F.R S	D Avery, Prof. C. Fawsitt, Dr. A. Holt (*Rec.*), Dr. N. V. Sidgwick.
SECTION C.[3] GEOLOGY.		
1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton (*Rec*).
1902. Belfast.....	Lieut.-Gen. C. A. McMahon, F.R.S.	H. L. Bowman, H. W. Monckton (*Rec.*), J. St. J. Phillips, H. J. Seymour.

[2] 'Chemistry and Mineralogy,' 1835–1894.
[3] 'Geology and Geography,' 1835–1850.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1903. Southport	Prof. W. W. Watts, M.A., M.Sc.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. W. Monckton (*Rec.*).
1904. Cambridge	Aubrey Strahan, F.R.S.	H. L. Bowman (*Rec.*), Rev. W. L. Carter, J. Lomas, H. Woods.
1905. SouthAfrica	Prof. H. A. Miers, M.A., D Sc., F.R.S.	H. L. Bowman (*Rec.*), J. Lomas, Dr. Molengraaff, Prof. A. Young, Prof. R. B. Young.
1906. York.....	G. W. Lamplugh, F.R.S.	H. L. Bowman (*Rec.*), 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 (*Rec.*).
1908. Dublin.....	Prof. John Joly, F R S.	Rev. W. L. Carter, J. Lomas (*Rec.*), Prof. S. H. Reynolds, H. J. Seymour.
1909 Winnipeg ..	Dr. A. Smith Woodward, F R S.	W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, R. T. Hodgson, Prof. S. H. Reynolds.
1910. Sheffield ...	Prof. A P. Coleman, F.R.S...	W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, B Hobson, Prof. S. H. Reynolds.
1911. Portsmouth	A. Harker, F.R.S.	Col. C. W. Bevis, W. L. Carter (*Rec*), Dr. A. R. Dwerryhouse, Prof. S. H. Reynolds.
1912. Dundee ...	Dr. B. N. Peach, F.R.S.	Prof. W. B. Boulton, A. W. R. Don, Dr. A. R. Dwerryhouse (*Rec.*), Prof. S. H. Reynolds.
1913. Birmingham	Prof. E J. Garwood, M A ...	Prof. W. S. Boulton, Dr. A R. Dwerryhouse (*Rec.*), F. Raw, Prof. S. H. Reynolds.
1914. Australia ...	Prof. Sir T. H Holland, F.R.S.	Dr. A. R Dwerryhouse (*Rec.*), E. F. Pittman, Prof. S. H. Reynolds, Prof. E W. Skeats.

SECTION D.[1]—ZOOLOGY.

1901. Glasgow ...	Prof. J. Cossar Ewart, F.R S	J. G. Kerr (*Rec*), J. Rankin, J. Y. Simpson.
1902. Belfast... ..	Prof. G. B. Howes, F.R.S. ...	Prof. J. G. Kerr, R. Patterson, J. Y. Simpson (*Rec.*).
1903. Southport	Prof. S. J. Hickson, F R.S. ...	Dr. J. H Ashworth, J. Barcroft, A. Quayle, Dr. J. Y. Simpson (*Rec.*), Dr. H. W. M. Tims.
1904. Cambridge	William Bateson, F.R S.	Dr. J. H. Ashworth, L Doncaster, Prof J. Y Simpson (*Rec.*), 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 (*Rec.*).
1906. York.....	J. J. Lister, F.R.S	Dr. J. H. Ashworth, L Doncaster, Oxley Grabham, Dr. H.W. M. Tims (*Rec.*).
1907. Leicester ...	Dr. W. E Hoyle, M.A.....	Dr. J. H. Ashworth, L. Doncaster, E. E. Lowe, Dr. H. W. M. Tims (*Rec.*).
1908. Dublin.....	Dr. S. F. Harmer, F.R.S.....	Dr. J. H. Ashworth, L. Doncaster, Prof. A. Fraser, Dr. H. W. M. Tims (*Rec.*).

[1] 'Zoology and Botany,' 1835–1847; 'Zoology and Botany, including Physiology,' 1848–1865; 'Biology,' 1866–1894.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1909. Winnipeg...	Dr. A. E. Shipley, F.R.S. ...	C. A. Baragar, C. L. Boulenger, Dr. J. Pearson, Dr. H. W. M. Tims (*Rec.*).
1910. Sheffield ...	Prof. G. C. Bourne, F.R.S. ...	Dr. J. H. Ashworth, L. Doncaster, T. J. Evans, Dr. H. W. M. Tims (*Rec.*).
1911. Portsmouth	Prof. D'Arcy W. Thompson, C.B.	Dr. J. H. Ashworth, C. Foran, R. D. Laurie, Dr. H. W. M. Tims (*Rec.*).
1912. Dundee ...	Dr. P. Chalmers Mitchell, F.R.S.	Dr. J. H. Ashworth, R. D. Laurie, Miss D. L. Mackinnon, Dr H. W M. Tims (*Rec.*).
1913. Birmingham	Dr. H. F. Gadow, F.R.S.....	Dr. J. H. Ashworth, Dr. C. L. Boulenger, R. D. Laurie, Dr. H. W. M. Tims (*Rec.*).
1914. Australia ...	Prof. A. Dendy, F.R.S.....	Dr. J. H. Ashworth, Dr. T. S. Hall, Prof. W. A. Haswell, R. D. Laurie, Prof. H. W. Marett Tims (*Rec.*)

SECTION E.[5]—GEOGRAPHY.

1901. Glasgow ...	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson (*Rec.*), E. Heawood, G. Sandeman, A. C. Turner.
1902. Belfast.....	Sir T. H. Holdich, K.C.B. ...	G. G. Chisholm (*Rec.*), 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 (*Rec*), Dr. A. J. Herbertson, E. A. Reeves, Capt. J. C. Underwood.
1904. Cambridge	Douglas W. Freshfield.....	E. Heawood (*Rec.*), 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 (*Rec.*), H. Y. Oldham.
1906. York.	Rt. Hon. Sir George Goldie, K.C.M.G., F.R.S.	E. Heawood (*Rec.*), Dr. A. J. Herbertson, E. A. Reeves, G. Yeld.
1907. Leicester ...	George G. Chisholm, M.A. ...	E. Heawood (*Rec.*), O. J. R. How arth, 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 (*Rec.*), E. A. Reeves.
1909. Winnipeg...	Col. Sir D. Johnston, K C.M.G., C.B., R.E.	G. G. Chisholm (*Rec.*), J. McFarlane, A. McIntyre.
1910. Sheffield ...	Prof. A. J. Herbertson, M.A., Ph.D.	Rev. W. J. Barton (*Rec.*), Dr. R. Brown, J. McFarlane, E. A. Reeves.
1911. Portsmouth	Col. C. F. Close, R.E., C.M.G.	J. McFarlane (*Rec.*), E. A. Reeves, W. P. Smith.
1912. Dundee ...	Col. Sir C. M. Watson, K.C.M.G.	Rev. W. J. Barton (*Rec.*), J. McFarlane, E. A. Reeves, D. Wylie.
1913. Birmingham	Prof. H. N. Dickson, D.Sc.	Rev. W. J. Barton (*Rec*), P. E. Martineau, J. McFarlane, E. A. Reeves.
1914. Australia ...	Sir C. P. Lucas, K.C.B., K.C.M.G.	J. A. Leach, J. McFarlane, H. Yule Oldham (*Rec.*), F. Poate.

[5] Section E was that of 'Anatomy and Medicine,' 1835–1840; of 'Physiology' (afterwards incorporated in Section D), 1841–1847. It was assigned to 'Geography and Ethnology,' 1851–1868; 'Geography,' 1869.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
SECTION F.[6]—ECONOMIC SCIENCE AND STATISTICS.		
1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan (*Rec.*), S. J. Chapman.
1902. Belfast ...	E. Cannan, M A., LL.D.	A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. A. Duffin.
1903. Southport	E. W. Brabrook, C.B.	A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. B. W. Ginsburg, G. Lloyd.
1904. Cambridge	Prof. Wm. Smart, LL D.	J. E. Bidwell, A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. B. W. Ginsburg.
1905. SouthAfrica	Rev. W. Cunningham, D.D., D.Sc.	R. à Ababrelton, A. L. Bowley (*Rec.*), Prof. H. E. S. Fremantle, H. O. Meredith.
1906. York.....	A. L. Bowley, M.A.	Prof. S. J. Chapman (*Rec.*), D. H. Macgregor, H. O. Meredith, B. S. Rowntree.
1907. Leicester...	Prof. W. J. Ashley, M.A.... ..	Prof. S J. Chapman (*Rec.*), D. H. Macgregor, H. O. Meredith, T. S. Taylor.
1908. Dublin.....	W. M. Acworth, M.A.	W G. S. Adams, Prof. S. J. Chapman (*Rec.*), 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.
1909. Winnipeg...	Prof. S. J. Chapman, M.A. ...	Prof. A. B. Clark, Dr. W. A. Manahan, Dr. W. R. Scott (*Rec.*).
1910. Sheffield ...	Sir H. Llewellyn Smith, K.C.B , M A.	C. R. Fay, H. O. Meredith (*Rec.*), Dr. W. R. Scott, R. Wilson.
1911. Portsmouth	Hon. W. Pember Reeves	C. R Fay, Dr. W. R. Scott (*Rec*), H. A. Stibbs.
1912. Dundee ...	Sir H. H. Cunynghame, K.C.B	C. R. Fay, Dr. W. R. Scott (*Rec.*), E. Tosh.
1913. Birmingham	Rev. P. H. Wicksteed, M A	C. R. Fay, Prof. A. W. Kirkaldy, Prof H. O. Meredith, Dr W. R. Scott (*Rec.*).
1914. Australia .	Prof. E. C. K. Gonner	Prof. R F. Irvine, Prof. A. W. Kirkaldy (*Rec*), G H. Knibbs, Prof. H O. Meredith.
SECTION G.[7]—ENGINEERING.		
1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W. E. Dalby, W. A. Price (*Rec.*).
1902. Belfast ...	Prof. J. Perry, F.R.S.	M. Barr, W. A. Price (*Rec.*), J. Wylie.
1903. Southport	C. Hawksley, M.Inst.C.E. ...	Prof. W. E. Dalby, W. T. Maccall, W. A. Price (*Rec.*).
1904. Cambridge	Hon. C. A. Parsons, F.R.S. ...	J. B. Peace, W. T. Maccall, W. A. Price (*Rec.*).
1905. SouthAfrica	Col. Sir C. Scott-Moncrieff, G.C.S.I., K.C M.G., R.E.	W. T. Maccall, W. B. Marshall (*Rec.*), Prof. H. Payne, E. Williams.
1906. York.....	J. A. Ewing, F.R.S.	W. T. Maccall, W. A. Price (*Rec.*), J. Triffit.
1907. Leicester...	Prof. Silvanus P. Thompson, F.R.S.	Prof. E. G. Coker, A. C. Harris, W. A. Price (*Rec.*), H. E. Wimperis.

[6] 'Statistics,' 1835–1855. [7] 'Mechanical Science,' 1836–1900.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1908. Dublin	Dugald Clerk, F.R.S.	Prof. E. G. Coker, Dr. W. E. Lilly, W. A. Price (*Rec.*), H. E. Wimperis.
1909. Winnipeg...	Sir W. H. White, K.C.B., F.R.S.	E. E. Brydone-Jack, Prof. E. G. Coker, Prof. E. W. Marchant, W. A. Price (*Rec.*).
1910. Sheffield ..	Prof. W. E. Dalby, M.A., M.Inst C E.	F. Boulden, Prof. E. G. Coker (*Rec.*), A. A. Rowse, H. E. Wimperis.
1911. Portsmouth	Prof. J. H. Biles, LL D., D.Sc.	H. Ashley, Prof. E. G. Coker (*Rec.*), A. A. Rowse, H. E. Wimperis.
1912. Dundee ...	Prof A. Barr, D.Sc.....	Prof. E. G. Coker (*Rec.*), A. R. Fulton, H. Richardson, A. A. Rowse, H. E. Wimperis.
1913. Birmingham	Prof. Gisbert Kapp, D.Eng....	Prof E. G. Coker (*Rec.*), J. Purser, A A. Rowse, H. E. Wimperis.
1914. Australia ...	Prof. E. G. Coker, D.Sc	Prof. G. W. O. Howe (*Rec.*), Prof. H. Payne, Prof. W. M. Thornton, Prof. W. H. Warren.

SECTION H.[8]—ANTHROPOLOGY.

1901. Glasgow ...	Prof. D. J. Cunningham, F R S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres (*Rec.*).
1902. Belfast ...	Dr. A. C. Haddon, F.R.S. ...	R. Campbell, Prof. A. F. Dixon, J. L. Myres (*Rec.*).
1903. Southport...	Prof. J Symington, F.R.S. ...	E. N. Fallaize, H. S. Kingsford, E. M. Littler, J. L Myres (*Rec.*).
1904. Cambridge	H. Balfour, M.A.	W. L. H. Duckworth, E. N. Fallaize, H. S. Kingsford, J. L. Myres (*Rec.*)
1905. SouthAfrica	Dr. A. C. Haddon, F.R.S ...	A. R. Brown, A. von Dessauer, E. S. Hartland (*Rec.*).
1906. York.....	E. Sidney Hartland, F.S.A....	Dr. G. A. Auden, E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall.
1907. Leicester ..	D. G. Hogarth, M.A.....	C. J. Billson, E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall.
1908. Dublin	Prof. W. Ridgeway, M.A. ...	E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall, L. E. Steele.
1909. Winnipeg...	Prof. J. L. Myres, M.A.	H. S. Kingsford (*Rec.*), Prof. C. J. Patten, Dr. F. C. Shrubsall.
1910. Sheffield ...	W. Crooke, B.A.	E. N. Fallaize (*Rec.*), H. S. Kingsford, Prof. C. J. Patten, Dr. F. C. Shrubsall.
1911. Portsmouth	W. H. R. Rivers, M.D., F.R.S	E. N. Fallaize (*Rec.*), H. S. Kingsford, E. W. Martindell, H. Rundle, Dr. F. C. Shrubsall.
1912. Dundee ...	Prof. G. Elliot Smith, F.R.S.	D. D. Craig, E. N. Fallaize (*Rec.*), E. W. Martindell, Dr. F. C. Shrubsall.
1913. Birmingham	Sir Richard Temple, Bart. ...	E N. Fallaize (*Rec.*), E. W. Martindell, Dr. F. C. Shrubsall, T. Yeates.
1914. Australia ...	Sir E. F. im Thurn, C.B., K.C.M.G.	Prof. R. J. A. Berry, Dr. B. Malinowski, Dr. R. R. Marett (*Rec.*), Prof. J. T. Wilson.

[8] Established 1884.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
SECTION I.[9]—PHYSIOLOGY (including EXPERIMENTAL PATHOLOGY AND EXPERIMENTAL PSYCHOLOGY).		
1901. Glasgow ...	Prof. J. G. McKendrick, F.R.S.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson (*Rec.*).
1902. Belfast ...	Prof. W. D. Halliburton, F.R.S.	J. Barcroft, Dr. W. A. Osborne (*Rec*), Dr. C. Shaw.
1904. Cambridge	Prof. C. S. Sherrington, F.R.S.	J. Barcroft (*Rec.*), Prof. T. G. Brodie, Dr. L. E. Shore.
1905. SouthAfrica	Col. D. Bruce, C.B., F.R.S. ...	J. Barcroft (*Rec.*), Dr. Baumann, Dr. Mackenzie, Dr. G. W. Robertson, Dr. Stanwell.
1906. York.....	Prof. F. Gotch, F.R.S.	J. Barcroft (*Rec*), 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 (*Rec.*), 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 (*Rec.*)
1909. Winnipeg...	Prof. E. H. Starling, F.R.S....	Dr. N. H. Alcock (*Rec.*), Prof. P. T. Herring, Dr. W. Webster.
1910. Sheffield ...	Prof. A. B. Macallum, F.R.S	Dr. H. G. M Henry, Keith Lucas, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1911. Portsmouth	Prof. J. S. Macdonald, B.A.	Dr. J. T. Leon, Dr. Keith Lucas, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1912. Dundee ...	Leonard Hill, F.R.S.	Dr. Keith Lucas, W. Moodie, Dr. H. E. Roaf (*Rec*), Dr. J. Tait.
1913. Birmingham	Dr. F. Gowland Hopkins, F.R.S.	C. L. Burt, Prof. P. T. Herring, Dr. T. G. Maitland, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1914. Australia...	Prof. B. Moore, F.R.S.	Prof. P. T. Herring (*Rec.*), Prof. T. H. Milroy, Prof. W. A. Osborne, Prof. Sir T. P. Anderson Stuart.
SECTION K.[10]—BOTANY.		
1901. Glasgow ...	Prof. I. B. Balfour, F.R.S. ...	D. T. Gwynne-Vaughan, G. F. Scott-Elliot, A. C. Seward (*Rec.*), H. Wager.
1902. Belfast ...	Prof. J. R. Green, F.R.S.	A. G. Tansley, Rev. C. H. Waddell, H. Wager (*Rec.*), R. H. Yapp.
1903. Southport	A. C. Seward, F.R.S.	H. Ball, A. G. Tansley, H. Wager (*Rec.*), 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 (*Rec*), T. B. Wood, R. H. Yapp.
1905. SouthAfrica	Harold Wager, F.R.S.	R. P. Gregory, Dr. Marloth, Prof. Pearson, Prof. R. H. Yapp (*Rec.*).
1906. York.....	Prof. F. W. Oliver, F.R.S. ...	Dr. A. Burtt, R. P. Gregory, Prof. A. G. Tansley (*Rec.*), Prof. R. H. Yapp.

[9] Established 1894. [10] Established 1895.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1907. Leicester ...	Prof. J. B. Farmer, F.R.S. ...	W. Bell, R. P. Gregory, Prof. A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1908. Dublin	Dr. F. F. Blackman, F.R.S....	Prof. H. H. Dixon, R. P. Gregory, A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1909. Winnipeg...	Lieut.-Col. D. Prain, C.I.E., F.R.S.	Prof. A. H. R. Buller, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp (*Rec.*).
	Sub-section of Agriculture— Major P. G. Craigie, C.B.	W. J. Black, Dr. E. J. Russell, Prof. J. Wilson.
1910. Sheffield ...	Prof. J. W. H. Trail, F.R.S	B. H. Bentley, R. P. Gregory, Prof D. T. Gwynne-Vaughan, Prof R. H. Yapp (*Rec.*).
1911. Portsmouth	Prof. F. E. Weiss, D.Sc.	C. G. Delahunt, Prof. D. T. Gwynne-Vaughan, Dr. C. E. Moss, Prof. R. H. Yapp (*Rec.*).
	Sub-section of Agriculture— W. Bateson, M.A., F.R.S.	J. Golding, H. R. Pink, Dr. E. J. Russell.
1912. Dundee ...	Prof. F. Keeble, D.Sc.	J. Brebner, Prof. D. T. Gwynne-Vaughan (*Rec.*), Dr. C. E. Moss, D. Thoday.
1913. Birmingham	Miss Ethel Sargant, F.L S. ..	W. B. Grove, Prof. D. T. Gwynne-Vaughan (*Rec.*), Dr. C. E. Moss, D. Thoday.
1914. Australia ...	Prof. F. O. Bower, F.R.S. ...	Prof. A. J. Ewart, Prof. T. Johnson (*Rec.*), Prof. A. A. Lawson, Miss E. N. Thomas.

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 (*Rec.*).
1902. Belfast ...	Prof. H. E. Armstrong, F.R.S.	Prof. R. A. Gregory, W. M. Heller (*Rec.*), 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 (*Rec.*), 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 (*Rec.*), Dr. C. W. Kimmins.
1905. South Africa	Prof. Sir R. C. Jebb, D.C.L., M.P.	A. D. Hall, Prof. Hele-Shaw, Dr. C. W. Kimmins (*Rec.*), J. R. Whitton.
1906. York.....	Prof. M. E. Sadler, LL.D. ...	Prof. R. A. Gregory, W. M. Heller (*Rec.*), Hugh Richardson.
1907. Leicester ...	Sir Philip Magnus, M.P.	W. D. Eggar, Prof. R. A. Gregory (*Rec.*), 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 (*Rec.*), Hugh Richardson.
1909. Winnipeg...	Rev. H. B. Gray, D.D.	W. D. Eggar, R. Fletcher, J. L. Holland (*Rec.*), Hugh Richardson.
1910. Sheffield ...	Principal H. A. Miers, F.R.S.	A. J. Arnold, W. D. Eggar, J. L. Holland (*Rec.*), Hugh Richardson.
1911. Portsmouth	Rt. Rev. J. E. C. Welldon, D.D.	W. D. Eggar, O. Freeman, J. L. Holland (*Rec.*), Hugh Richardson.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1912. Dundee ...	Prof. J. Adams, M.A.	D. Berridge, Dr. J. Davidson, Prof. J. A. Green (*Rec.*), Hugh Richardson.
1913. Birmingham	Principal E. H. Griffiths, F.R.S.	D. Berridge, Rev. S. Blofeld, Prof. J. A. Green (*Rec.*), H. Richardson.
1914. Australia ...	Prof. J. Perry, F.R.S.	P. Board, C. A. Buckmaster, Prof. J A. Green (*Rec.*), J. Smyth.

SECTION M.—AGRICULTURE.

1912. Dundee ...	T. H Middleton, M.A.....	Dr. C. Crowther, J. Golding, Dr. A. Lauder, Dr. E J. Russell (*Rec.*).
1913. Birmingham	Prof. T. B. Wood, M.A.	W E. Collinge, Dr. C. Crowther, J Golding, Dr. E. J. Russell (*Rec.*)
1914. Australia ...	A. D. Hall, F R.S.....	Prof T. Cherry, J. Golding (*Rec.*), Dr. A. Lauder, Prof R. D. Watt.

CHAIRMEN AND SECRETARIES OF THE CONFERENCES OF DELEGATES OF CORRESPONDING SOCIETIES, 1901-14.[1]

(For 1915, see p. lii)

Date and Place	Chairmen	Secretaries
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.
1909. London ...	Dr. A. C Haddon, F R.S. ...	W. P D. Stebbing.
1910. Sheffield ...	Dr. Tempest Anderson.....	W P. D Stebbing.
1911. Portsmouth	Prof. J. W. Gregory, F R.S....	W. P. D. Stebbing.
1912. Dundee ...	Prof. F. O Bower, F.R.S. ...	W. P. D. Stebbing.
1913. Birmingham	Dr. P. Chalmers Mitchell, F.R.S.	W. P. D. Stebbing.
1914. Le Havre...	Sir H. George Fordham ...	W. Mark Webb.

EVENING DISCOURSES, 1901-14.

(For 1915, see *General Meetings*, p. li.)

Date and Place	Lecturer	Subject of Discourse
1901. Glasgow ...	Prof. W. Ramsay, F.R.S.	The Inert Constituents of the Atmosphere.
	Francis 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.

[1] Established 1885.

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.
1909. Winnipeg...	Dr. A. E. H. Tutton, F.R.S....	The Seven Styles of Crystal Architecture.
	Prof. W. A. Herdman, F.R.S.	Our Food from the Waters.
	[1] Prof. H. B. Dixon, F.R.S...	The Chemistry of Flame.
	[1] Prof. J. H. Poynting, F.R.S.	The Pressure of Light.
1910. Sheffield ...	Prof. W. Stirling, M.D	Types of Animal Movement.[2]
	D. G. Hogarth	New Discoveries about the Hittites.
1911. Portsmouth	Dr. Leonard Hill, F.R.S.....	The Physiology of Submarine Work.
	Prof. A. C. Seward, F.R.S ...	Links with the Past in the Plant World.
1912. Dundee ...	Prof. W. H. Bragg, F.R.S. ...	Radiations Old and New.
	Prof. A. Keith, M.D.....	The Antiquity of Man.
1913. Birmingham	Sir H. H. Cunynghame, K.C.B.	Explosions in Mines and the Means of Preventing Them.
	Dr. A. Smith Woodward, F.R.S.	Missing Links among Extinct Animals
1914. Australia:		
Adelaide	Sir Oliver J. Lodge, F.R.S....	The Ether of Space.
	Prof. W. J. Sollas, F.R.S. ...	Ancient Hunters.
Melbourne	Prof. E. B. Poulton, F.R.S ...	Mimicry.
	Dr. F. W. Dyson, F.R.S. ...	Greenwich Observatory.
Sydney ...	Prof. G. Elliot Smith, F.R.S.	Primitive Man.
	Sir E. Rutherford, F.R.S. ...	Atoms and Electrons.
Brisbane	Prof. H. E. Armstrong, F.R.S.	The Materials of Life.
	Prof. G. W. O. Howe	Wireless Telegraphy.
	Sir E. A. Schäfer, F.R.S.....	Australia and the British Association

[1] 'Popular Lectures,' delivered to the citizens of Winnipeg.
[2] Repeated, to the public, on Wednesday, September 7.

LECTURES TO THE OPERATIVE CLASSES, 1901–11.

Date and Place	Lecturer	Subject of Lecture
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.
1910. Sheffield ...	C. T. Heycock, F.R.S.	Metallic Alloys.
1911. Portsmouth	Dr. H. R. Mill	Rain.

PUBLIC OR CITIZENS' LECTURES, 1912–14.

(For 1915, see p. lxviii.)

Date and Place	Lecturer	Subject of Lecture
1912. Dundee ...	Prof. B. Moore, D.Sc.	Science and National Health.
	Prof. E. C. K. Gonner, M.A.	Prices and Wages.
	Prof. A. Fowler, F.R.S.	The Sun.
1913. Birmingham	Dr. A. C. Haddon, F.R.S. ...	The Decorative Art of Savages.
	Dr. Vaughan Cornish	The Panama Canal.
	Leonard Doncaster, M.A. ...	Recent Work on Heredity and its Application to Man.
	Dr. W. Rosenhain, F.R.S. ...	Metals under the Microscope.
	Frederick Soddy, F.R.S.....	The Evolution of Matter.
1914. Australia:		
Perth ...	Prof. W. A. Herdman, F.R.S.	Why we Investigate the Ocean.
	Prof. A. S. Eddington, F.R.S.	Stars and their Movements.
	H. Balfour, M.A.	Primitive Methods of Making Fire.
	Prof. A. D. Waller, F.R.S. ...	Electrical Action of the Human Heart.
Kalgoorlie	C. A. Buckmaster, M.A.	Mining Education in England.
Adelaide	Prof E. C. K. Gonner, M.A.	Saving and Spending.
Melbourne	Dr. W. Rosenhain, F.R.S. ...	Making of a Big Gun.
	Prof. H. B. Dixon, F.R.S. ...	Explosions.
Sydney ...	Prof. B. Moore, F.R.S.....	Brown Earth and Bright Sunshine.
	Prof. H. H. Turner, P.R.S. ...	Comets.
Brisbane	Dr. A. C. Haddon, F.R.S. ...	Decorative Art in Papua.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes, 1901-1914.

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
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

	£	s.	d.
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 Committee	20	0	0
	£815	13	2

1904.

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

1905.

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 Nitroamines	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 of Egyptian Troops	10	0	0
Excavations on Roman Sites in Britain	10	0	0
Anthropometric Investigations	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 Nitroamines	10	0	0
Fauna and Flora of the British Trias	7	8	11
Crystalline Rocks of Anglesey	30	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Frog	10	0	0
Higher Crustacea	15	0	0
Freshwater Fishes of South Africa	50	0	0
Rainfall and Lake and River Discharge	10	0	0
Excavations in Crete	100	0	0
Lake Village at Glastonbury	40	0	0
Excavations on Roman Sites in Britain	30	0	0
Anthropometric Investigations in the British Isles	30	0	0
State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	20	0	0
Effect of Climate upon Health and Disease	20	0	0
Research on South African Cycads	14	19	4
Peat Moss Deposits	25	0	0
Studies suitable for Elementary Schools	5	0	0
Corresponding Societies Committee	25	0	0
	£882	0	9

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
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 on 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 Nitroamines	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

	£	s.	d.
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
	£1,157	18	8

1909.

Seismological Observations ..	60	0	0
Investigation of the Upper Atmosphere by means of Kites	10	0	0
Magnetic Observations at Falmouth	50	0	0
Establishing a Solar Observatory in Australia	50	0	0
Wave-length Tables of Spectra	9	16	0
Study of Hydro aromatic Substances	15	0	0
Dynamic Isomerism.....	35	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	30	0	0
Fauna and Flora of British Trias	8	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	8	0	0
Palæozoic Rocks of Wales and the West of England	9	0	0
Igneous and Associated Sedimentary Rocks of Glensaul	11	13	9
Investigations at Biskra	50	0	0
Table at the Zoological Station at Naples	100	0	0
Heredity Experiments.....	10	0	0
Feeding Habits of British Birds	5	0	0
Index Animalium.....	75	0	0
Investigations in the Indian Ocean	35	0	0
Gaseous Explosions	75	0	0
Excavations on Roman Sites in Britain	5	0	0
Age of Stone Circles.....	30	0	0
Researches in Crete	70	0	0
The Ductless Glands	35	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Reflex Muscular Rhythm.....	10	0	0
Anæsthetics	25	0	0
Mental and Muscular Fatigue	27	0	0
Structure of Fossil Plants ...	5	0	0
Botanical Photographs.....	10	0	0
Experimental Study of Heredity.....	30	0	0
Symbiosis between Turbellarian Worms and Algæ	10	0	0
Survey of Clare Island.....	65	0	0
Curricula of Secondary Schools	5	0	0
Corresponding Societies Committee	21	0	0
	£1,014	9	9

1910.

Measurement of Geodetic Arc in South Africa	100	0	0
Republication of Electrical Standards Reports	100	0	0
Seismological Observations...	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism.....	35	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
South African Strata	5	0	0
Fossils of Midland Coalfields	25	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium.....	75	0	0
Heredity Experiments	15	0	0
Feeding Habits of British Birds	5	0	0
Amount and Distribution of Income	15	0	0
Gaseous Explosions	75	0	0
Lake Villages in the neighbourhood of Glastonbury...	5	0	0
Excavations on Roman Sites in Britain	5	0	0
Neolithic Sites in Northern Greece...	5	0	0
The Ductless Glands	40	0	0
Body Metabolism in Cancer...	20	0	0
Anæsthetics	25	0	0
Tissue Metabolism	25	0	0
Mental and Muscular Fatigue	18	17	0
Electromotive Phenomena in Plants.....	10	0	0
Structure of Fossil Plants ...	10	0	0
Experimental Study of Heredity.....	30	0	0

	£	s.	d.
Survey of Clare Island	30	0	0
Corresponding Societies Committee	20	0	0
	£963	17	0

1911.

Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Grant to International Commission on Physical and Chemical Constants	30	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	25	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	15	0	0
Influence of Carbon, &c., on Corrosion of Steel	15	0	0
Crystalline Rocks of Anglesey	2	0	0
Mammalian Fauna in Miocene Deposits, Bugti Hills, Baluchistan	75	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Feeding Habits of British Birds	5	0	0
Belmullet Whaling Station	30	0	0
Map of Prince Charles Foreland	30	0	0
Gaseous Explosions	90	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Age of Stone Circles	30	0	0
Artificial Islands in Highland Lochs	10	0	0
The Ductless Glands	40	0	0
Anæsthetics	20	0	0
Mental and Muscular Fatigue	25	0	0
Electromotive Phenomena in Plants	10	0	0
Dissociation of Oxy-Hæmoglobin	25	0	0
Structure of Fossil Plants	15	0	0
Experimental Study of Heredity	45	0	0
Survey of Clare Island	20	0	0
Registration of Botanical Photographs	10	0	0
Mental and Physical Factors involved in Education	10	0	0
Corresponding Societies Committee	20	0	0
	£922	0	0

1912.

Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	30	0	0
Grant to International Commission on Physical and Chemical Constants	30	0	0
Further Tabulation of Bessel Functions	15	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	30	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	10	0	0
Study of Plant Enzymes	30	0	0
Erratic Blocks	5	0	0
Igneous and Associated Rocks of Glensaul, &c	15	0	0
List of Characteristic Fossils	5	0	0
Sutton Bone Bed	15	0	0
Bembridge Limestone at Creechbarrow Hill	20	0	0
Table at the Zoological Station at Naples	50	0	0
Index Animalium	75	0	0
Belmullet Whaling Station	20	0	0
Secondary Sexual Characters in Birds	10	0	0
Gaseous Explosions	60	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Artificial Islands in Highland Lochs	10	0	0
Physical Character of Ancient Egyptians	40	0	0
Excavation in Easter Island	15	0	0
The Ductless Glands	35	0	0
Calorimetric Observations on Man	40	0	0
Structure of Fossil Plants	15	0	0
Experimental Study of Heredity	35	0	0
Survey of Clare Island	20	0	0
Jurassic Flora of Yorkshire	15	0	0
Overlapping between Secondary and Higher Education	1	18	6
Curricula, &c., of Industrial and Poor Law Schools	10	0	0
Influence of School Books upon Eyesight	3	9	0
Corresponding Societies Committee	25	0	0
Collections illustrating Natural History of Isle of Wight	40	0	0
	£845	7	6

1913.

Seismological Investigations	60	0	0
Investigation of the Upper Atmosphere	50	0	0
International Commission on Physical and Chemical Constants	40	0	0

	£	s.	d.
Further Tabulation of Bessel Functions	30	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	30	0	0
Transformation of Aromatic Nitroamines	20	0	0
Study of Plant Enzymes	30	0	0
Igneous and Associated Rocks of Glensaul, &c	10	0	0
List of Characteristic Fossils	5	0	0
Exploration of the Upper Old Red Sandstone of Dura Den	75	0	0
Geology of Ramsey Island	10	0	0
Old Red Sandstone Rocks of Kiltorcan	15	0	0
Table at the Zoological Station at Naples	50	0	0
Ditto (Special Grant)	50	0	0
Nomenclature Animalium Genera et Sub-genera	100	0	0
Belmullet Whaling Station	15	0	0
Ditto (Special Grant)	10	0	0
Gaseous Explosions	80	0	0
Lake Villages in the Neighbourhood of Glastonbury	5	0	0
Age of Stone Circles (Special Grant)	15	0	0
Artificial Islands in the Highlands of Scotland	5	0	0
Excavations on Roman Sites in Britain	15	0	0
Hausa Manuscripts	20	0	0
The Ductless Glands	40	0	0
Calorimetric Observations on Man	45	0	0
Dissociation of Oxy-Haemoglobin at High Altitudes	15	0	0
Structure and Function of the Mammalian Heart	20	0	0
Structure of Fossil Plants	15	0	0
Jurassic Flora of Yorkshire	4	12	4
Vegetation of Ditcham Park, Hampshire	45	0	0
Influence of School Books on Eyesight	9	4	9
Corresponding Societies Committee	25	0	0
	£978	17	1

1914.

Seismological Investigations	130	0	0
Investigation of the Upper Atmosphere	25	0	0
International Committee on Physical and Chemical Constants	40	0	0
Calculation of Mathematical Tables	20	0	0
Disposal of Copies of the 'Binary Canon'	4	9	0
Study of Hydro-aromatic Substances	15	0	0
Dynamic Isomerism	25	0	0
Transformation of Aromatic Nitroamines	15	0	0
Study of Plant Enzymes	25	0	0
Correlation of Crystalline Form with Molecular Structure	25	0	0
Study of Solubility Phenomena	10	0	0
List of Characteristic Fossils	5	0	0
Geology of Ramsey Island	10	0	0
Fauna and Flora of Trias of Western Midlands	10	0	0
Critical Sections in Lower Palæozoic Rocks	15	0	0
Belmullet Whaling Station	20	0	0
Nomenclature Animalium Genera et Sub-genera	50	0	0
Antarctic Whaling Industry	75	0	0
Maps for School and University Use	40	0	0
Gaseous Explosions	50	0	0
Stress Distributions in Engineering Materials	50	0	0
Lake Villages in the Neighbourhood of Glastonbury	20	0	0
Age of Stone Circles	20	0	0
Artificial Islands in the Highlands of Scotland	5	0	0
Excavations on Roman Sites in Britain	20	0	0
Anthropometric Investigations in Cyprus	50	0	0
Palæolithic Site in Jersey	50	0	0
The Ductless Glands	35	0	0
Calorimetric Observations on Man	40	0	0
Structure and Function of the Mammalian Heart	30	0	0
Binocular Combination of Kinematograph Pictures	0	17	0
Structure of Fossil Plants	15	0	0
Jurassic Flora of Yorkshire	5	0	0
Flora of the Peat of the Kennet Valley	15	0	0
Vegetation of Ditcham Park	14	4	3
Physiology of Heredity	30	0	0
Breeding Experiments with Œnotheras	19	17	4
Mental and Physical Factors involved in Education	20	0	0
Influence of School Books on Eyesight	2	8	9
Character, Work, and Maintenance of Museums	10	0	0
Corresponding Societies Committee	25	0	0
	£1,086	16	4

REPORT OF THE COUNCIL, 1914–15.

I. Sir Arthur J. Evans, F.R.S., has been unanimously nominated by the Council to fill the office of President of the Association for 1916–17 (Newcastle-on-Tyne Meeting).

II. Australian Meeting : The Council resolved—

> 'That the Council of the British Association for the Advancement of Science, at its first Meeting in London since the return of Members from Australia, desires to place on record its high appreciation of the generous reception given to the Members of the Overseas Party throughout the Commonwealth by representatives of the Governments of the Commonwealth and the States, and by other authorities and Australian citizens generally, on the occasion of the Meeting of the Association in Australia in 1914. The Council hereby expresses its grateful thanks for the hospitality, privileges and concessions extended so freely to visiting Members, and also for the willing and valuable collaboration of all those who undertook so successfully the work of organisation in Australia in connection with the Meeting.'

III. Resolutions referred to the Council on behalf of the General Committee in Australia for consideration, and, if desirable, for action, were dealt with as follows :—

From Sections A and C.

> 'That in view of the fact that meteorites, which convey information of world-wide importance, are sometimes disposed of privately, in such a way as to deprive the public of this information, the Council be requested to take such steps as may initiate international legislation on the matter.'

It was resolved that the Royal Society be asked to approach the International Association of Academies in this matter. Communications on this Resolution received from the South African Association for the Advancement of Science were transmitted to the Royal Society.

From Section A.

> 'That the British Association learns with great satisfaction that the State Government of Victoria has put a definite annual grant at the disposal of the Director of the Melbourne Observatory for printing the work already done at the Observatory. It is very desirable that every effort should be made to publish as soon as possible the arrears accumulated during the past thirty years.'

It was resolved that the Council of the Royal Astronomical Society be consulted, and a letter subsequently received from the Secretary of the Society in support of the Resolution was forwarded to the proper Government Authority in Melbourne.

From Sections C and E.

'The Committees of the Geographical and Geological Sections of the British Association wish to draw attention to the high scientific value and practical importance of systematic glacial observation in New Zealand, and venture to urge upon the favourable consideration of the Government of the Dominion the great importance of continuing and extending the work which is now being done in this direction by Officers of the Government, as far as possible in conformity with the methods adopted by the Commission Internationale des Glaciers.'

Following the report of a Committee appointed by the Council to consider this matter, the Council supported the resolution and ordered it to be forwarded to the Prime Minister of New Zealand.

From Sections D and K.

'It is with much pleasure that we ascertain that a Bill has been prepared by the present Government of South Australia for the establishment of a reserve of 300 square miles situated on the western end of Kangaroo Island for the preservation of the fauna and flora, which are fast being exterminated on the mainland, and that this reserve will be placed under the control of a Board nominated by the University of Adelaide and the Government. We trust that this Bill will become law at an early date.'

The above resolution was confirmed and forwarded to the proper Authorities in South Australia.

Other Resolutions were referred to the Council dealing with the establishment of a Bureau of Weights and Measures in Australia, with the establishment of Bench-marks on Islands in the Coral Seas, with a Gravity Survey in Australia, and with the 1:1,000,000 Map of the World (Australian sheets).

Committees have been appointed to consider and report upon these resolutions, but it was decided that it would be inappropriate to put forward resolutions on these subjects at the present time, and the Committees were informed accordingly.

The following RESOLUTION was also received:—

'That in view of the successful issue of the Australian Meeting of the Association, the Council be asked to consider the best means of bringing into closer relationship the British Association and scientific representatives from the Dominions overseas.'

It was considered inexpedient to deal with the above resolution at present, but the General Officers were instructed to bring forward a scheme for giving effect to it when circumstances should be more favourable.

IV. MANCHESTER MEETING :—

At the Meeting of Council in November, 1914, it was resolved :—

> 'That the Council of the British Association, realising the special difficulty attending the holding of a Meeting of the Association at the present time, offer to the citizens of Manchester to adopt any modification of the Meeting they may think desirable, even to complete postponement, unless they are informed that the desire in Manchester is to carry out the invitation.'

The following RESOLUTION passed by the Local Executive Committee in Manchester was received in December :—

> 'That owing to the uncertainty of the present situation, the decision with regard to the holding of the Meeting of the British Association in Manchester be postponed until the middle of March, and that in the meantime the preparations for the Meeting be suspended.'

At the Meeting of Council in March, 1915, the following resolution was received :—

> 'That the Council of the British Association be informed that in the opinion of the Manchester Executive Committee it will be impossible to receive the British Association this year in the manner that was contemplated or with the accommodation and hospitality which Manchester has extended to the Association on former occasions. But the Executive Committee desire that the long continuity of the yearly meetings should not be broken, and prefer that the meeting should be held although restricted to its more purely scientific functions, and would be glad to make preparations for such a meeting and could hope to offer suitable accommodation for all sections and scientific discourses of the Association.'

It was unanimously resolved that the Meeting be held on the lines indicated in the above Resolution. The Council concurred in the proposed alterations of date, to September 7–11 inclusive, and empowered the General Officers to make, or agree upon with the Manchester Executive, any special arrangements in connection with the Meeting in view of the unusual conditions under which it was to be held.

One such arrangement was that, at the instance of the Manchester Executive, teachers in elementary and secondary schools and students of recognised institutions for higher education in Manchester and district should be admitted as Associates at a special fee of 10*s*.

In a number of instances military duties prevented Secretaries of Sections and other Officers appointed by the Council from accepting office.

V. The Council approved a suggestion that the Association might be instrumental in arranging lectures to soldiers in training or convalescent,

and correspondence passed between the General Secretaries and the War Office Authorities. The authorities welcomed the suggestion, but subsequently indicated that soldiers in camps would shortly be more fully occupied with field-training, and it was decided to be useless to proceed with the formation of a list of lecturers. The authorities were informed accordingly, with an expression of regret that the matter had not been taken up earlier, owing to the absence of the Officers of the Association in Australia.

VI. CAIRD FUND :—

The Council has made the following grants during the year, additional to annual grants previously made :—

Committee on Gravity Observations at Sea (Section A) .	£100
Mr. F. Sargent, Bristol University, in connection with his astronomical work	£10
Organising Committee of Section F, in connection with its enquiry into Outlets for Labour after the War . .	£100

VII. CONFERENCE OF DELEGATES and CORRESPONDING SOCIETIES COMMITTEE :—

(1) The following Nominations are made by the Council :—

Conference of Delegates.—Prof. Sir T H. Holland (*Chairman*), Mr W. Whitaker (*Vice-Chairman*), Mr. W. Mark Webb (*Secretary*).

Corresponding Societies Committee.—Mr. W. Whitaker (*Chairman*), Mr. W Mark Webb (*Secretary*), Rev. J. O. Bevan, Sir Edward Brabrook, Sir H G. Fordham, Dr. J. G. Garson, Principal E. H. Griffiths, Dr. A. C. Haddon, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.

(2) The Council have resolved to propose to the General Committee that the titles of the Chairman and Vice-Chairman of the Conference of Delegates be changed to President and Vice-President respectively, and that these titles be substituted in Rule 4, ch. xi , and that of President for Chairman in Rule 1, ch. iii.

VIII. The Council have received reports from the General Treasurer during the past year. In consequence of the early removal of the books, &c., from London to Australia, it was not possible to prepare the usual annual accounts last year. These have now been audited and are presented to the General Committee together with the accounts for the current year.

IX. The retiring members of the Council are :—

By seniority.—Major P. G. Craigie, Mr. A. D. Hall.
By least attendance.—Mr. Alfred Lodge, Major H. G. Lyons, Prof. R. Meldola.

The Council nominated the following new members :—

Prof. W. A. Bone,
Prof. H. N. Dickson,
Prof. T. B. Wood.

leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of ordinary members is as follows :—

Prof. H. E. Armstrong.
Prof. W. A. Bone.
Sir E. Brabrook.
Prof. W. H. Bragg.
Dr. Dugald Clerk.
Mr. W. Crooke.
Prof. A. Dendy.
Prof. H. N. Dickson.
Dr. F. A. Dixey.
Prof. H. B. Dixon.
Sir F. W. Dyson.
Principal E. H. Griffiths.
Dr. A. C. Haddon.
Prof. W. D. Halliburton.
Sir Everard im Thurn.
Prof. J. L. Myres.
Sir E. Rutherford.
Miss E. R. Saunders.
Prof. E. H. Starling.
Dr. J. J. H. Teall.
Prof. S. P. Thompson.
Prof. F. E. Weiss.
Prof. T. B. Wood.

X. The General Officers have been nominated by the Council as follows :—

General Treasurer : Prof. J. Perry.
General Secretaries : Prof. W. A. Herdman.
Prof. H. H. Turner.

XI. The following have been admitted as members of the General Committee :—

Mr. E. Heron Allen.
Prof. E. H. Barton.
Prof. T. H. Havelock.
Dr. W. F. Hume.
Mr. J. B. C. Kershaw.
Mr. T. C. Lewis.

Dr. **THE GENERAL TREASURER IN ACCOUNT WITH THE ADVANCEMENT OF SCIENCE,**

RECEIPTS.

	£ s. d.	£ s. d.
To Balance brought forward: On General Account.....	2,613 11 5	
Less Overspent on 'Caird Fund'	226 6 6	
		2,387 4 11
Life Compositions (including Transfers)		215 0 0
Annual Subscriptions		4,516 0 0
New Annual Members' Subscriptions		366 0 0
Sale of Associates' Tickets		298 0 0
Sale of Publications		189 1 3
Interest on Deposits:		
Lloyds Bank, Birmingham		41 17 8
Commonwealth Bank of Australia		47 0 8
Unexpended Balances of Grants returned		17 13 9
Dividends on Investments:		
Consols, 2½ per Cent.....	130 10 4	
India 3 per Cent.	98 17 9	
Gt. Indian Peninsula Railway 'B' Annuity	28 8 8	
		257 16 9
Dividends on 'Caird Fund' Investments:		
India 3½ per Cent. Stock	81 3 9	
London and North-Western Railway Consolidated 4 per Cent. Pref. Stock	77 10 6	
London and South-Western Railway do.	92 5 10	
Canada 3½ per Cent. Registered Stock	80 0 6	
		331 0 7
Proceeds of Sale of £400 London and North-Western Railway Consolidated 4 per Cent. Preference Stock ('Caird Fund' Investment)		394 9 0

Investments.

Nominal Amount £ s. d.		
5,701 10 5	2½ per Cent. Consolidated Stock	
3,600 0 0	India 3 per Cent. Stock	
879 14 9	£43 Great Indian Peninsula Railway 'B' Annuity	
2,627 0 10	India 3½ per Cent. Stock, 'Caird Fund'	
2,100 0 0	London and North-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'	
2,500 0 0	London and South-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'	
2,500 0 0	Canada 3½ per Cent. 1930–1950 Registered Stock, 'Caird Fund'	
81 7 2	Sir Frederick Bramwell's Gift of 2½ per Cent. Self-cumulating Consolidated Stock	
£19,989 13 2		£9,064 4 7

JOHN PERRY, *General Treasurer.*

WITH THE BRITISH ASSOCIATION FOR THE July 1, 1914, to June 30, 1915. *Cr.*

PAYMENTS.

	£	s.	d.
By Rent and Office Expenses	96	8	2
Salaries, &c.	798	10	1
Printing, Binding, &c.	1,165	6	8
Expenses of Australian Meeting	371	14	7
Advances for Travelling Expenses of Invited Members	75	0	0
Grants to Research Committees:—			

	£	s.	d.
Seismological Observations	130	0	0
Annual Table of Constants and Numerical Data	40	0	0
Calculation of Mathematical Tables	25	0	0
Dynamic Isomerism	40	0	0
Transformation of Aromatic Nitroamines	20	0	0
Study of Plant Enzymes	10	0	0
Chemical Investigation of Natural Plant Products	50	0	0
Influence of Weather Conditions on Nitrogen Acids in Rainfall	40	0	0
Non-Aromatic Diazonium Salts	5	0	0
Biology of Abrolhos Islands	40	0	0
Collection of Marsupials	100	0	0
Survey of Stor Fjord, Spitsbergen	50	0	0
Antarctic Bathymetrical Chart	100	0	0
Fatigue from Economic Standpoint	30	0	0
Gaseous Explosions	50	0	0
Stress Distributions	50	0	0
Lake Villages in the Neighbourhood of Glastonbury	20	0	0
Age of Stone Circles	10	0	0
Palæolithic Site in Jersey	50	0	0
Excavations in Malta	10	0	0
Gazetteer and Map of Native Tribes in Australia	20	0	0
Electromotive Phenomena of the Heart	20	0	0
Metabolism of Phosphates	20	0	0
Structure of Fossil Plants	6	0	0
Physiology of Heredity	45	0	0
Renting of Cinchona Botanic Station, Jamaica	25	0	0
Influence of Percentages of Oxygen	50	0	0
Australian Cycadaceæ	25	0	0
Sections of Australian Fossil Plants	25	0	0
Influence of School Books on Eyesight	5	0	0
Scholarships, &c., held by University Students	3	2	8
Character, Work, and Maintenance of Museums	20	0	0
Corresponding Societies Committee	25	0	0
			1,159. 2 8
Grants made from 'Caird Fund'			410 0 0

	£	s.	d.	£	s.	d.
Balance at Lloyds Bank, Birmingham (with accrued Interest) (including Sir James Caird's Gift, Radio-Activity Investigation, of £1,000)	1,718	9	11			
Balance at Commonwealth Bank of Australia (with accrued Interest)	3,227	0	1			
Balance at Bank of England, Western Branch: On 'Caird Fund'	92	3	1			
Less General Account overdrawn	49	10	8			
				42	12	5
						4,988 2 5
						£9,064 4 7

An Account of approximately £1,180 is outstanding due to Messrs. Spottiswoode & Co.

I have examined the above Account with the Books and Vouchers of the Association, and certify the same to be correct. I have also verified the Balances at the Bankers, and have ascertained that the Investments are registered in the names of the Trustees.

W. B. KEEN, *Chartered Accountant.*
August 5, 1915.

Approved—
EDWARD BRABROOK,
EVERHARD IM THURN, } *Auditors.*

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 F G S 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 G, 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	215	36
1873 Aug 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	226	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

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

[*Continued on p.* xlviii.

at Annual Meetings of the Association.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of 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	—	1516 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	246	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
101	48	412	316	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	443	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	119	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	1172 2 6	1871
280	80	937	912	13	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	671	17	2578	2615 0 0	725 16 6	1878
239	74	529	319	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	811	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	2153	2532 0 0	995 0 6	1886
510	244	1985	193	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1021	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	1103	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900

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

[*Continued on p.* xlix.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
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
1909, Aug. 25.....	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31	Sheffield.. .	Rev. Prof. T. G. Bonney, F R.S.	293	26
1911, Aug. 30	Portsmouth	Prof. Sir W. Ramsay, K.C B , F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schafer, F.R.S.	288	14
1913, Sept. 10	Birmingham	Sir Oliver J. Lodge, F.R.S.	376	40
1914, July-Sept. ..	Australia	Prof. W. Bateson, F.R.S.	172	13
1915, Sept. 7	Manchester	Prof. A. Schuster, F.R.S.	212	19

¶ Including 848 Members of the South African Association
‡‡ Grants from the Caird Fund are not included in this and subsequent sums.

ANALYSIS OF ATTENDANCES AT

[*The total attendances for the years* 1832,

Average attendance at 79 *Meetings* : 1858.

	Average Attendance
Average attendance at 5 Meetings beginning during *June, between* 1833 *and* 1860	1260
Average attendance at 4 Meetings beginning during *July, between* 1841 *and* 1907	1122
Average attendance at 32 Meetings beginning during *August, between* 1836 *and* 1911	1927
Average attendance at 37 Meetings beginning during *September, between* 1831 *and* 1913	1977
Attendance at 1 Meeting held in *October, Cambridge*, 1862 . . .	1161

Meetings beginning during August.

Average attendance at—

4	Meetings	beginning	during	the	1st	week	in	*August*	(1st- 7th)	.	1905
5	„	„	„	„	2nd	„	„	„	(8th-14th)	.	2130
9	„	„	„	„	3rd	„	„	„	(15th-21st)	.	1802
14	„	„	„	„	4th	„	„	„	(22nd-31st)	.	1935

at Annual Meetings of the Association—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
374	131	794	246	20	1912	£2046 0 0	£920 9 11	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
290**	162	789	90	7	1468	1623 0 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0 0	963 17 0	1910
349	61	414	81	31	1241	1176 0 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0 0	978 17 1‡‡	1913
139	4160‖	539‖	—	21	5014‖	4873 0 0	1086 16 4	1914
287	116	628*	141	8	1441	1406 0 0	1159 2 8	1915

** Including 137 Members of the American Association.

‖ Special arrangements were made for Members and Associates joining locally in Australia, see Report, 1914, p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.

* Including Student's Tickets, 10*s.* (see *Report of Council*, IV. p. xli).

THE ANNUAL MEETINGS, 1831–1913.

1835, 1843, *and* 1844 *are unknown.*]

Meetings beginning during September.

Average attendance at—

		Average Attendance
13	Meetings beginning during the 1st week in *September* (1st– 7th).	2131
17	,, ,, ,, ,, 2nd ,, ,, ,, (8th–14th).	1906
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 (1907, July 31) beginning during the 5th week in *July* (29th–31st)	1647
Attendance at 1 Meeting (1862, October 1) beginning during the 1st week in *October* (1st–7th)	1161

GENERAL MEETINGS AT MANCHESTER.

On Tuesday, September 7, at 8.30 P.M., in the Free Trade Hall, Professor W. Bateson, F.R.S., resigned the office of President to Professor Arthur Schuster, F.R.S. The following telegram from the Right Hon. Sir Henry Roscoe, F.R.S., was read :—

My best wishes for the success of the Meeting I greatly regret that I cannot be present to support my distinguished friend, the President. I send my love to Manchester.

The following letter from the Rt. Hon. A. J. Balfour, M.P., F.R.S., forwarded by Sir Henry Roscoe, was also read :—

Admiralty, Whitehall: September 2, 1915.

MY DEAR SIR HENRY ROSCOE,—I am sorry that pressure of public business makes it impossible for me to attend the Meeting of the British Association at Manchester

I should have particularly valued an opportunity of taking a share (as past President) in its labours: partly because the scene of these is a city with which I was long and closely connected, partly because I should like to have borne testimony (if that be required) to the patriotic zeal with which the Royal Society, of which your distinguished President is Secretary, have placed all their scientific resources at the disposal of the Government for the purposes of the War. Although the Association meets this year in circumstances which deprive the gathering of much of its social charm, I am sure that its scientific labours will be not less fruitful than in years gone by

With every good wish for its success,

Believe me,
Yours sincerely,
(Signed) ARTHUR JAMES BALFOUR

On taking the Chair, Professor Arthur Schuster moved, and it was unanimously resolved, that the following message be forwarded to His Majesty the King :—

We, the members of the British Association for the Advancement of Science, this day in our 85th Congress assembled humbly beg to express our devoted loyalty to Your Majesty's person and to Your Majesty's Government in this crisis of our national affairs. Landing in Australia at the moment of the declaration of war, we witnessed the extraordinary manifestations of loyalty which were displayed throughout that great Commonwealth. During our earlier visits to Canada and South Africa a like spirit of loyalty and imperial fellowship found expression in the cordiality of the reception given to us By these visits we have endeavoured to strengthen the bonds which unite all parts of Your Majesty's Empire

We beg leave on the present occasion to assure Your Majesty that the Association as a whole and every individual member thereof are whole-heartedly anxious to devote all their energies to assisting Your Majesty's Government in the task of bringing the War to a victorious conclusion.

SCHUSTER, President.

Professor Schuster then delivered an Address, for which see page 3.

On Wednesday, September 8, the following reply was received from His Majesty the King, and was communicated to the members assembled at the various sectional meetings :—

The President of the British Association, Manchester.

I have received with much satisfaction the message you have forwarded on behalf the members of the British Association testifying to their loyalty to the Crown and to my Government in this time of national crisis. The outbursts of loyalty which the members of the Association witnessed in their past visits throughout Australia, Canada, and South Africa have been gloriously demonstrated by those imperishable deeds achieved on the heights of Gallipoli, in the trenches of Flanders,

and upon the waterless plains of German South Africa. In gratefully accepting the resolution that the Association one and all will do everything in their power to bring the War to a final victory, I recognise with deep appreciation the valuable services which are being rendered to this end by the men of science.

GEORGE R. I.

On Wednesday evening, September 8, at 8 P.M., the Rt. Hon. the Lord Mayor of Manchester held an Evening Reception in the Manchester Municipal School of Technology.

On Thursday, September 9, at 8.30 P.M., in the Free Trade Hall, Mr. H. W. T. Wager, F.R.S., delivered a discourse on 'The Behaviour of Plants in response to Light.'

On Friday, September 10, at 8.30 P.M., in the Free Trade Hall, Professor R. A. Sampson, F.R.S., delivered a discourse on 'A Census of the Skies.'

After the above discourse (the occasion being the concluding General Meeting), the following resolution was unanimously adopted on the motion of the President:—

That the cordial thanks of the British Association be extended to the Rt. Hon. the Lord Mayor and Corporation of the City of Manchester for their hearty welcome, to the Governing Bodies of the University and other institutions which have kindly placed their buildings and resources at the disposal of the Association, to the firms which have thrown open their works to the inspection of members, and, finally, to the honorary local officers and their able assistants, and to the General and Executive Committees and individual members thereof, for the admirable arrangements made for the Meeting under exceptional and trying circumstances.

OFFICERS OF SECTIONS AT THE MANCHESTER MEETING, 1915.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President—Sir F. W. Dyson, M.A., LL.D., F.R.S. *Vice-Presidents.*—Prof. H. Lamb, LL.D., D.Sc., F.R.S.; Prof. Sir E. Rutherford, D.Sc., F.R.S.: Prof. H. H. Turner, D.Sc., F.R.S. *Secretaries.*—Prof. A. S. Eddington, M.A., M.Sc., F.R.S (*Recorder*); E. Gold, M.A.; A. O. Rankine D.Sc.; W. Makower, M.A., D.Sc.

SECTION B.—CHEMISTRY.

President.—Prof. W. A. Bone, D.Sc., F.R.S. *Vice-Presidents.*—Prof. W. J. Pope, M.A., LL.D., F.R.S.; Prof. W. P. Wynne, D.Sc., F.R.S. *Secretaries.*—A. Holt, D.Sc. (*Recorder*); C. H. Desch, D.Sc., Ph.D.; H. F. Coward, D.Sc.

SECTION C.—GEOLOGY.

President.—Prof. Grenville A. J. Cole. *Vice-Presidents.*—Rev. Prof. T. G. Bonney, Sc.D., F.R.S.; Hon. Prof. W. Boyd Dawkins, F.R.S.; Prof. E. J. Garwood, F.R.S.; Major Sir T. H. Holland, K.C.I.E., F.R.S. *Secretaries.*—W. Lower Carter, M.A. (*Recorder*); Dr. W. T. Gordon; Dr. D. M. S. Watson; Dr. G. Hickling.

SECTION D.—ZOOLOGY.

President.—Prof. E. A. Minchin, M.A., F.R.S. (*in absentiâ*). *Vice-Presidents.*—Prof. A. Dendy, D.Sc., F.R.S.; H. F. Gadow, M.A., Ph.D., F.R.S.; Prof. S. J. Hickson, F.R.S. *Secretaries.*—J. H. Ashworth, D.Sc. (*Recorder*); F. Balfour Browne, M.A., F.R.S.E.; R. Douglas Laurie, M.A.; J. Stuart Thomson, Ph.D.

SECTION E.—GEOGRAPHY.

President.—Major H. G. Lyons, D.Sc., F.R.S. (*in absentiâ*). *Vice-Presidents.*—Prof. H. N. Dickson, D Sc.; H. Nuttall, M.P.; G. G. Chisholm; Prof. J. W. Gregory, F.R.S.; H. Yule Oldham. *Secretaries.*—J. McFarlane, M.A. (*Recorder*); Prof. R. N. Rudmose Brown, D.Sc.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—Prof. W. R. Scott, M.A., Litt.D. *Vice-Presidents.*—Sidney Arnold; R. Noton Barclay; Prof. E. C. K. Gonner; Sir Charles Macara. *Secretaries.*—Prof. A. W. Kirkaldy, M.A., M.Com. (*Recorder*); E. J. W. Jackson; B. Ellinger.

SECTION G.—ENGINEERING.

President.—H. S. Hele-Shaw, D.Sc., LL.D., F.R.S. *Vice-Presidents.*—Prof. E. G. Coker, M A., D.Sc.; Prof. Gisbert Kapp, M.Sc., D.Eng.; Right Hon. Sir Wm. Mather; Dr. Edward Hopkinson; Robert Matthews; de Courcey Meade; Prof. J. E. Petavel, F.R.S. *Secretaries.*—Prof. G. W. O. Howe, D.Sc. (*Recorder*); J. Frith, M.Sc.; W. Cramp, D.Sc.

SECTION H.—ANTHROPOLOGY.

President.—Prof. C. G. Seligman, M.D. *Vice-Presidents*—Prof. W. B. Anderson; Prof. R. S. Conway; Sir Laurence Gomme, F.S.A.; Sir Everard F. im Thurn, C.B., K.C.M.G.; Sir Richard Temple, Bart., C.I.E. *Secretaries.*—E. N. Fallaize, B.A. (*Recorder*); F. C. Shrubsall, M.A., M.D.; J. S. B. Stopford, M.B., Ch.B.

SECTION I.—PHYSIOLOGY.

President.—Prof. W. M. Bayliss, D.Sc., F.R.S. *Vice-Presidents.*—Prof. Benjamin Moore, D Sc., F.R.S.; Prof. W. Stirling, M.D. *Secretaries.*—Prof. P. T. Herring, M.D. (*Recorder*); C. L. Burt (Sec. Sub-Section Psychology); J. Tait, M.D., D.Sc.; F. W. Lamb, B.A., M.D.

SECTION K.—BOTANY.

President.—Prof. W. H. Lang, M.B., D.Sc., F R.S. *Vice-Presidents.*—Prof. F. O. Bower, D.Sc., F.R.S.; Sir Daniel Morris, K.C.M.G.; Prof. F. W. Oliver, F.R.S.; Miss Ethel Sargant, F.L.S.; H. W. T. Wager, F.R S. *Secretaries.*—C. E. Moss, D.Sc. (*Recorder*); D. Thoday, M.A.; R. S. Adamson, M.A., B.Sc

SECTION L.—EDUCATIONAL SCIENCE.

President.—Mrs. Henry Sidgwick. *Vice-Presidents.*—Principal E. H. Griffiths, M.A., D Sc., F.R.S.; Prof. J. Perry, LL.D, F.R S. *Secretaries*—Prof. J. A. Green, M.A. (*Recorder*); D. Berridge, M.A.; H. Richardson, M.A.; F. A. Bruton, M.A.

SECTION M.—AGRICULTURE.

President.—R. H. Rew, C.B. *Vice-Presidents.*—A. D. Hall, M.A., F.R.S.; T. H. Middleton, C.B.; Prof. T. B. Wood, M.A.; Prof. S. Coppenz (Louvain); Prof. W. Somerville, D.Sc.; Prof. W. Bateson, F.R.S. *Secretaries.*—Prof. C. Crowther, M.A., Ph.D. (*Recorder*); A. Lauder, D.Sc.; T. J. Young, M.Sc.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

Chairman.—Major Sir T. H. Holland, K.C.I.E., F.R.S. *Vice-Chairman.*—W. Whitaker, F.R.S. *Secretary.*—W. Mark Webb.

LIST OF GRANTS: MANCHESTER, 1915

RESEARCH COMMITTEES, ETC., APPOINTED BY THE GENERAL COMMITTEE AT THE MANCHESTER MEETING: SEPTEMBER, 1915.

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
SECTION A.—MATHEMATICS AND PHYSICS.		
Seismological Observations.	*Chairman.*—Professor H H. Turner. *Secretary.*—Mr. J. J. Shaw. Mr. J. E. Crombie, Mr. Horace Darwin, Mr. C. Davison, Dr. R. T. Glazebrook, Professors H. Lamb, J. W. Judd, and C. G. Knott, Sir J. Larmor, Professors A. E. H. Love, H. M. Macdonald, R. Meldola, J. Perry, and H. C. Plummer, Mr. W. E. Plummer, Professors R. A. Sampson and A. Schuster, Dr. G T. Walker, and Mr. G. W. Walker.	130 0 0
Annual Tables of Constants and Numerical Data, chemical, physical, and technological.	*Chairman.*—Sir W. Ramsay. *Secretary.*—Dr. W. C. McC. Lewis.	40 0 0
Calculation of Mathematical Tables.	*Chairman.*—Professor M. J. M. Hill. *Secretary.*—Professor J. W. Nicholson. Mr. J. R. Airey, Mr. T. W. Chaundy, Professor Alfred Lodge, Professor L. N. G. Filon, Sir G. Greenhill, Mr. G. Kennedy, and Professors E.W Hobson, A. E. H. Love, H. M. Macdonald, G. B. Mathews, and A. G. Webster.	35 0 0
SECTION B.—CHEMISTRY.		
Dynamic Isomerism.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. T. M. Lowry. Professor Sydney Young, Dr. Desch, Sir J. J. Dobbie, and Dr. M. O. Forster.	20 0 0
The Transformation of Aromatic Nitroamines and allied substances, and its relation to Substitution in Benzene Derivatives.	*Chairman.*—Professor F. S. Kipping. *Secretary.*—Professor K. J. P. Orton. Sir S. Ruhemann and Dr. J. T. Hewitt.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Study of Plant Enzymes, particularly with relation to Oxidation.	*Chairman* —Mr. A. D. Hall. *Secretary.*—Dr. E. F. Armstrong. Professor H. E. Armstrong, Professor F. Keeble, and Dr. E. J. Russell.	10 0 0
Correlation of Crystalline Form with Molecular Structure.	*Chairman.*—Professor W. J. Pope. *Secretary.*—Professor H. E. Armstrong. Mr. W. Barlow and Professor W. P. Wynne.	10 0 0
Study of Solubility Phenomena	*Chairman.*—Professor H. E. Armstrong. *Secretary* —Dr J. V. Eyre. Dr E F. Armstrong, Professor A Findlay, Dr. T. M. Lowry, and Professor W. J. Pope.	5 0 0
The Influence of Weather Conditions upon the Amounts of Nitrogen Acids in the Rainfall and the Atmosphere.	*Chairman.*—Professor Orme Masson. *Secretary* —Mr. V G. Anderson Mr. D. Avery and Mr H. A Hunt.	20 0 0
Research on Non-Aromatic Diazonium Salts.	*Chairman.*—Dr F. D Chattaway. *Secretary* —Professor G.T.Morgan Mr. P. G W. Bayly and Dr. N. V Sidgwick.	8 10 0
To report on the Botanical and Chemical Characters of the Eucalypts and their Correlation.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Mr H. G. Smith. Dr. Andrews, Mr R. T Baker, Professor F. O. Bower, Mr. R. H. Cambage, Professor A. J. Ewart, Professor C.B Fawsitt, Dr.Heber Green, Dr. Cuthbert Hall, Professors Orme Masson, Rennie, and Robinson, and Mr. St. John.	30 0 0
Absorption Spectra and Chemical Constitution of Organic Compounds.	*Chairman.*—Sir J. J. Dobbie. *Secretary.*- Mr. E. E. C. Baly. Mr. A. W. Stewart	10 0 0
Section C.—GEOLOGY.		
To consider the preparation of a List of Characteristic Fossils.	*Chairman* —Professor P. F. Kendall. *Secretary.*—Mr. W. Lower Carter. Professor W. S. Boulton, Professor G. Cole, Dr. A. R. Dwerryhouse, Professors J. W. Gregory, Sir T. H. Holland, G. A. Lebour, and S. H. Reynolds, Dr. Marie C. Stopes, Mr. Cosmo Johns, Dr. J. E. Marr, Dr. A. Vaughan, Professor W. W. Watts, Mr. H. Woods, and Dr. A. Smith Woodward.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Old Red Sandstone Rocks of Kiltorcan, Ireland.	*Chairman.*—Professor Grenville Cole. *Secretary.*—Professor T. Johnson. Dr. J. W. Evans, Dr. R. Kidston, and Dr. A. Smith Woodward.	7 0 0
To excavate Critical Sections in the Palæozoic Rocks of England and Wales	*Chairman.* — Professor W. W. Watts. *Secretary* — Professor W. G Fearnsides. Professor W S. Boulton, Mr E. S Cobbold, Professor E. J. Garwood, Mr. V. C. Illing, Dr. Lapworth, and Dr. J. E. Marr.	20 0 0
To excavate Critical Sections in Old Red Sandstone Rocks at Rhynie, Aberdeenshire.	*Chairman.*—Dr J Horne. *Secretary.*—Dr. W Mackie Drs J. S. Flett, W. T. Gordon, G. Hickling, R Kidston, B N Peach, and D M S Watson	25 0 0
To investigate the Flora of Lower Carboniferous times as exemplified at a newly discovered locality at Gullane, Haddingtonshire	*Chairman.*—Dr. R. Kidston. *Secretary.*—Dr. W T. Gordon Dr. J S Flett, Professor E. J Garwood, Dr J Horne, and Dr. B. N Peach.	8 0 0
Section D.—ZOOLOGY.		
To investigate the Biological Problems incidental to the Belmullet Whaling Station	*Chairman* — Dr. A. E. Shipley. *Secretary.*—Professor J. Stanley Gardiner. Mr. R. M. Barrington, Professor W. A. Herdman, Rev. W. Spotswood Green, Mr. E S. Goodrich, Dr. S. F. Harmer, Dr. E W. L. Holt, and Professor H. W. Marett Tims.	25 0 0
Section E.—GEOGRAPHY.		
To investigate the Conditions determining the Selection of Sites and Names for Towns, with special reference to Australia.	*Chairman.*—Sir C. P. Lucas. *Secretary.*—Mr. H. Yule Oldham. Mr. G. G. Chisholm and Professor J. L. Myres.	15 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £	s.	d.
SECTION F.—ECONOMIC SCIENCE AND STATISTICS.				
The question of Fatigue from the Economic Standpoint, if possible in co-operation with Section I, Sub-section of Psychology.	*Chairman.*—Professor Muirhead. *Secretary.*—Miss B. L. Hutchins. Miss A. M. Anderson, Professor F. A. Bainbridge, Mr. E. Cadbury, Professor S. J. Chapman, Mr. P. Sargant Florence, Professor Stanley Kent, Miss M. C. Matheson, Mrs. Meredith, Dr. C. S. Myers, Mr. C. K. Ogden, Mr. J. W. Ramsbottom, and Dr. Jenkins Robb.	40	0	0
Industrial Unrest.	*Chairman.* — Professor A. W. Kirkaldy. *Secretary.*—Mr. Egbert Jackson. Sir Hugh Bell, Professor S. J. Chapman, Archdeacon Cunningham, Mr. W. J. Davis, Mr. Alfred Evans, J.P., Professor E. C. K Gonner, Mr. Howard Heaton, Sir C. W. Macara, and Professor W. R. Scott.	20	0	0
Replacement of Men by Women in Industry.	*Chairman* —Professor W. R Scott *Secretary.*—Miss Enfield. Miss Ashley, Mr. C. W. Bowerman, M.P., Archdeacon Cunningham, Mrs. B. Drake, Miss Franklin, Professor E. C K. Gonner, Mr. St G. Heath, Professor Hobhouse, Mr. Egbert Jackson, Mrs. Pember Reeves, and Mr. J. A. Seddon.	90	0	0
The Effects of the War on Credit, Currency, and Finance.	*Chairman.*—Professor W. R. Scott *Secretary.*— Mr. J E. Allen. Professor C. F. Bastable, Sir Edward Brabrook, Professor Dicksee, Professor F. Y. Edgeworth, Mr. B. Ellinger, Mr. A. H. Gibson, Professor E. C. K. Gonner, Mr. F. W. Hirst, Professor Kirkaldy, Mr. D. M. Mason, M P., Profesor J. S. Nicholson, Sir R. H. Inglis Palgrave, Mr. E. Sykes, and Mr. Sidney Webb.	25	0	0
SECTION G.—ENGINEERING.				
To investigate Engineering Problems affecting the future Prosperity of the Country.	*Chairman.*—Dr. H. S. Hele-Shaw. *Secretary.*—Professor G. W. O. Howe. Professor E. G. Coker, Sir R. Hadfield, Sir W. Mather, Mr. W. Maw, and Mr. C. E. Stromeyer.	10	0	0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Investigation of Gaseous Explosions, with special reference to Temperature.	*Chairman.*—Dr. Dugald Clerk. *Secretary.*—Professor W. E. Dalby. Professors W. A. Bone, F. W. Burstall, H. L. Callendar, E. G. Coker, and H. B. Dixon, Drs. R. T. Glazebrook and J. A. Harker, Colonel H. C. L. Holden, Professors B. Hopkinson and J. E. Petavel, Captain H. Riall Sankey, Professor A. Smithells, Professor W. Watson, Mr. D. L. Chapman, and Mr. H. E. Wimperis.	50 0 0
To report on certain of the more complex Stress Distributions in Engineering Materials.	*Chairman.*—Professor J. Perry. *Secretaries.* — Professors E. G. Coker and J. E. Petavel. Professor A. Barr, Dr. Chas. Chree, Mr. Gilbert Cook, Professor W. E. Dalby, Sir J. A. Ewing, Professor L. N. G. Filon, Messrs. A. R. Fulton and J. J. Guest, Professors J. B. Henderson and A. E. H. Love, Mr. W. Mason, Sir Andrew Noble, Messrs. F. Rogers and W. A. Scoble, Dr. T. E. Stanton, and Mr. J. S. Wilson.	40 0 0
Section H.—Anthropology.		
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	*Chairman.*—Sir C. H. Read. *Secretary.*—Mr. H. Balfour. Dr. G. A. Auden, Professor W. Ridgeway, Dr. J. G. Garson, Sir A. J. Evans, Dr. R. Munro, Professors Boyd Dawkins and J. L. Myres, Mr. A. L. Lewis, and Mr H. Peake.	25 0 0
To investigate the Physical Characters of the Ancient Egyptians.	*Chairman.*—Professor G. Elliot Smith. *Secretary.*—Dr. F. C. Shrubsall. Dr. F. Wood-Jones, Dr. A. Keith, and Dr. C. G. Seligman.	15 0 0
To excavate a Palæolithic Site in Jersey.	*Chairman.*—Dr. R. R. Marett. *Secretary.*— Mr. G. de Gruchy. Dr. C. W. Andrews, Mr. H. Balfour, Dr. Dunlop, Professor A. Keith, and Colonel Warton.	25 0 0
To conduct Archæological Investigations in Malta.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. T. Ashby. Mr. H. Balfour, Dr. A. C. Haddon, and Dr. R. R. Marett.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To report on the Distribution of Bronze Age Implements.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Mr. H. Peake. Professor W. Ridgeway, Mr. H. Balfour, Sir C. H. Read, Professor W. Boyd Dawkins, Dr. R. R. Marett, and Mr. O. G. S. Crawford.	5 0 0
SECTION I.—PHYSIOLOGY.		
The Ductless Glands.	*Chairman.*—Sir E. A. Schäfer. *Secretary.*—Professor Swale Vincent. Dr. A. T. Cameron and Professor A. B. Macallum.	20 0 0
Further Researches on the Structure and Function of the Mammalian Heart.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Professor Stanley Kent. Dr. Florence Buchanan.	20 0 0
SECTION K.—BOTANY.		
The Structure of Fossil Plants.	*Chairman.*—Professor F.W Oliver. *Secretary*—Professor F. E Weiss Mr E Newell Arber, Professor A. C. Seward, and Dr. D H. Scott.	2 0 0
Experimental Studies in the Physiology of Heredity.	*Chairman.*—Professor F. F. Blackman *Secretary*—Mr. R. P. Gregory Professors Bateson and Keeble, and Miss E. R. Saunders	45 0 0
The Renting of Cinchona Botanic Station in Jamaica.	*Chairman.*—Professor F. O. Bower *Secretary.*—Professor R H Yapp. Professors R. Buller, F. W Oliver, and F. E. Weiss.	12 10 0
SECTION L.—EDUCATIONAL SCIENCE.		
To inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.	*Chairman.*—Dr. C. S. Myers. *Secretary.*—Professor J. A. Green. Professor J. Adams, Dr. G. A. Auden, Sir E. Brabrook, Dr. W. Brown, Mr. C. Burt, Professor E. P. Culverwell, Mr. G. F. Daniell, Miss B. Foxley, Professor R. A. Gregory, Dr. C. W. Kimmins, Professor W. McDougall, Professor T. P. Nunn, Dr. W. H. R. Rivers, Dr. F. C. Shrubsall, Professor H. Bompas Smith, Dr. C. Spearman, and Mr. A. E. Twentyman.	20 0 0
To inve... lems a... perity of...		

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
The Influence of School Books upon Eyesight.	*Chairman.*—Dr. G. A. Auden. *Secretary.*—Mr. G. F. Daniell. Mr. C. H. Bothamley, Mr. W. D. Eggar, Professor R. A. Gregory, Dr. N. Bishop Harman, Mr. J. L. Holland, Dr. W. E. Sumpner, Mr. A. P. Trotter, and Mr. Trevor Walsh.	5 0 0
To examine, inquire into, and report on the Character, Work, and Maintenance of Museums, with a view to their Organisation and Development as Institutions for Education and Research; and especially to inquire into the Requirements of Schools.	*Chairman.*—Professor J. A. Green. *Secretaries.*—Mr. H. Bolton and Dr. J. A. Clubb. Dr. F. A. Bather, Mr C. A. Buckmaster, Mr. M. D. Hill, Dr. W. E. Hoyle, Professors E. J. Garwood and P. Newberry, Sir H. Miers, Sir Richard Temple, Mr. H. Hamshaw Thomas, Professor F. E. Weiss, Mrs. J. White, Rev. H. Browne, Drs. A. C. Haddon and H. S Harrison, Mr. Herbert R. Rathbone, and Dr. W. M. Tattersall.	15 0 0
The Effects of the 'Free-place' System upon Secondary Education.	*Chairman.*—Mr. C. A. Buckmaster. *Secretary.*—Mr. D. Berridge. Mr. C. H. Bothamley, Miss S. A. Burstall, Miss L. J. Clarke, Miss B. Foxley, Dr. W. Garnett, Professor R A. Gregory, Mr. J. L. Paton, Professor H. Bompas Smith, Dr. H. Snape, and Miss Walter.	10 0 0
CORRESPONDING SOCIETIES.		
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. W. Mark Webb. Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Dr. J. G. Garson, Principal E. H. Griffiths, Dr. A. C. Haddon, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.	25 0 0

2. *Not receiving Grants of Money.**

Subject for Investigation, or Purpose	Members of Committee
SECTION A.—MATHEMATICS AND PHYSICS.	
Investigation of the Upper Atmosphere.	*Chairman.*—Sir Napier Shaw. *Secretary.*—Captain E. Gold. Mr. C. J. P. Cave, Mr. W. H. Dines, Dr. R. T. Glazebrook, Sir J. Larmor, Professor J. E. Petavel, Professor A. Schuster, and Lieut.-Col W. Watson.
Radiotelegraphic Investigations.	*Chairman.*—Sir Oliver Lodge. *Secretary.*—Dr. W. H. Eccles. Mr S. G. Brown, Dr. C. Chree, Sir F. W. Dyson, Professor A. S. Eddington, Dr. Erskine-Murray, Professors J. A. Fleming, G. W. O. Howe, H. M. Macdonald, and J. W. Nicholson, Sir H. Norman, Captain H. R. Sankey, Professor A. Schuster, Sir N. Shaw, Professor S. P. Thompson, and Professor H. H. Turner.
To aid the work of Establishing a Solar Observatory in Australia.	*Chairman.*—Professor H. H. Turner. *Secretary.*—Dr. W. G. Duffield. Rev. A. L. Cortie, Dr. W. J. S. Lockyer, Mr. F. McClean, and Professors A. Schuster and H. H. Turner.
*Determination of Gravity at Sea	*Chairman.*—Professor A. E. Love. *Secretary.*—Professor W. G. Duffield. Mr. T. W. Chaundy, and Professors A. S. Eddington and H. H. Turner.
SECTION B.—CHEMISTRY.	
The Study of Hydro-Aromatic Substances.	*Chairman.*—Professor W. H. Perkin. *Secretary.*—Professor A. W. Crossley. Dr. M. O. Forster, Dr. Le Sueur, and Dr. A. McKenzie.
Chemical Investigation of Natural Plant Products of Victoria.	*Chairman.*—Professor Orme Masson. *Secretary.*—Dr. Heber Green. Mr. J. Cronin, and Mr. P. R. H. St. John.
Research on the Utilization of Brown Coal Bye-Products.	*Chairman.*—Professor Orme Masson. *Secretary.*—Mr. P. G. W. Bayly. Mr. D. Avery.
Fuel Economy; Utilization of Coal; Smoke Prevention.	*Chairman.*—Professor W. A. Bone. *Secretary.*—Mr. E. D. Simon. Professors P. Phillips Bedson and G. T. Beilby, Mr. E. Bury, Mr. J. Cobb, Mr. J. B. Cohen, Professor H. B. Dixon, Mr. Th. Gray, Dr. H. S. Hele-Shaw, Messrs. L. T. O'Shea, J. E. Stead, and R. Threlfall, and Professor W. P. Wynne

* Excepting the case of Committees receiving grants from the Caird Fund.

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

Subject for Investigation, or Purpose	Members of Committee
SECTION C.—GEOLOGY.	
Fauna and Flora of the Trias of the Western Midlands.	*Chairman.*—Mr. G. Barrow. *Secretary.*—Mr. L. J. Wills. Dr. J. Humphreys, Mr. W. Campbell Smith, Mr. D. M. S. Watson, and Professor W. W. Watts.
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor E. J. Garwood. *Secretaries.*—Professors W. W. Watts and S. H. Reynolds. Mr. G. Bingley, Dr. T. G. Bonney, and Messrs. C V. Crook, R. Kidston, A. S. Reid, J. J. H. Teall, R. Welch, and W. Whitaker.
To consider the Preparation of a List of Stratigraphical Names, used in the British Isles, in connection with the Lexicon of Stratigraphical Names in course of preparation by the International Geological Congress.	*Chairman.*—Dr. J. E. Marr. *Secretary.*—Dr. F. A. Bather. Professor Grenville Cole, Mr. Bernard Hobson, Professor Lebour, Dr. J. Horne, Dr. A. Strahan, and Professor W. W. Watts.
To consider the Nomenclature of the Carboniferous, Permo-Carboniferous, and Permian Rocks of the Southern Hemisphere.	*Chairman.*—Professor T. W. Edgeworth David. *Secretary.*—Professor E. W. Skeats. Mr. W. S. Dun, Sir T. H. Holland, Professor Howchin, Mr. A. E. Kitson and Mr. G. W. Lamplugh, Dr. A. W. Rogers, Professor A. C. Seward, Dr. D. M. S. Watson, and Professor W. G. Woolnough.
SECTION D.—ZOOLOGY.	
Nomenclator Animalium Genera et Sub-genera.	*Chairman.*—Dr. Chalmers Mitchell. *Secretary.*—Rev. T. R. R. Stebbing. Dr. M Laurie, Professor Marett Tims, and Dr. A. Smith Woodward.
An investigation of the Biology of the Abrolhos Islands and the North-west Coast of Australia (north of Shark's Bay to Broome), with particular reference to the Marine Fauna.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor W. J. Dakin. Dr. J. H. Ashworth and Professor F. O. Bower.
To obtain, as nearly as possible, a Representative Collection of Marsupials for work upon (*a*) the Reproductive Apparatus and Development, (*b*) the Brain.	*Chairman.*—Professor A. Dendy. *Secretaries.*—Professors T. Flynn and G. E. Nicholls. Professor E B. Poulton and Professor H. W. Marett Tims.

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

Subject for Investigation, or Purpose	Members of Committee
*To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Mr E. S. Goodrich. *Secretary.*—Dr. J. H. Ashworth. Mr. G. P. Bidder, Professor F. O. Bower, Drs. W. B. Hardy and S. F. Harmer, Professor S. J. Hickson, Sir E. Ray Lankester, Professor W. C. McIntosh, and Dr. A. D. Waller.
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.*—Professor S. J. Hickson. *Secretary.*—Dr W. M Tattersall. Professors G. C. Bourne, M. Hartog, W. A. Herdman, A. Dendy, and J. Graham Kerr, Dr. P. Chalmers Mitchell, and Professors E. B. Poulton and J. Stanley Gardiner.
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 J. P. Hill, and Mr. E. S Goodrich.
Zoological Bibliography and Publication.	*Chairman.*—Professor E. B. Poulton. *Secretary.*—Dr F. A. Bather. Drs W. E. Hoyle and P. Chalmers Mitchell.
Section E.—GEOGRAPHY.	
To aid in the preparation of a Bathymetrical Chart of the Southern Ocean between Australia and Antarctica.	*Chairman.*—Professor T. W. Edgeworth David. *Secretary.*—Captain J. K. Davis. Professor J. W. Gregory, Sir C. P. Lucas, and Professor Orme Masson.
Section G.—ENGINEERING.	
To consider and report on the Standardization of Impact Tests.	*Chairman.*—Professor W. H. Warren. *Secretary.*—Mr. J. Vicars. Mr. G. A. Julius, Professor A. H. Gibson, Mr. Houghton, and Professor Payne.
Section H.—ANTHROPOLOGY.	
To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Mr. Willoughby Gardner. Professor W. Ridgeway, Sir Arthur J. Evans, Sir C. H. Read, Mr. H. Balfour, and Dr. A. Bulleid.
To conduct Anthropometric Investigations in the Island of Cyprus.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. F. C. Shrubsall. Dr. A. C. Haddon.
To prepare and publish Miss Byrne's Gazetteer and Map of the Native Tribes of Australia.	*Chairman.*—Professor Baldwin Spencer. *Secretary.*—Dr. R. R. Marett. Mr. H. Balfour.

* See note on page lx.

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

Subject for Investigation, or Purpose	Members of Committee
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Sir C. H. Read. *Secretary.*— Dr. G. A. Auden, Mr. E. Heawood, and Professor J. L. Myres.
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, Sir A. J. Evans, Professor W. Ridgeway, and Dr. F. C. Shrubsall.
To conduct Excavations in Easter Island.	*Chairman.*—Dr. A. C. Haddon. *Secretary.*—Dr. W. H. R. Rivers. Mr. R. R. Marett and Dr. C. G. Seligman.
The Teaching of Anthropology.	*Chairman.*—Sir Richard Temple. *Secretary.*—Dr. A. C. Haddon. Sir E. F. im Thurn, Mr. W. Crooke, Dr. C. G. Seligman, Professor G. Elliot Smith, Dr. R. R. Marett, Professor P. E. Newberry, Dr. G. A. Auden, Professors T. H. Bryce, A. Keith, P. Thompson, R. W. Reid, H. J. Fleure, and J. L. Myres, Sir B. C. A. Windle, and Professors R. J. A. Berry, Baldwin Spencer, Sir T. Anderson Stuart, and E. C. Stirling.
To excavate Early Sites in Macedonia.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Mr. A. J. B. Wace. Professors R. C. Bosanquet and J. L. Myres.
To investigate and ascertain the Distribution of Artificial Islands in the lochs of the Highlands of Scotland.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Prof. J. L. Myres. Professors T. H. Bryce and W. Ridgeway, Dr. A. Low, and Mr. A. J. B. Wace.
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Professor R. C. Bosanquet. Dr. T. Ashby, Mr. Willoughby Gardner, and Professor J. L. Myres.

Section I.—Physiology.

To acquire further knowledge, Clinical and Experimental, concerning Anæsthetics—general and local—with special reference to Deaths by or during Anæsthesia, and their possible diminution.	*Chairman.*—Dr. A. D. Waller. *Secretary.*— Dr. Blumfeld, Mr. J. A. Gardner, and Dr. G. A. Buckmaster.
Electromotive Phenomena in Plants.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Mrs. Waller. Professors J. B. Farmer, T. Johnson, and Veley, and Dr. F. O'B. Ellison.

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

Subject for Investigation, or Purpose	Members of Committee
To investigate the Physiological and Psychological Factors in the production of Miners' Nystagmus.	*Chairman.*—Professor J. H. Muirhead. *Secretary.*—Dr. T. G. Maitland. Dr. J. Jameson Evans and Dr. C. S. Myers.
The Significance of the Electro-motive Phenomena of the Heart.	*Chairman.*—Professor W. D Halliburton. *Secretary.*—Dr. Florence Buchanan. Professor A. D. Waller.
Metabolism of Phosphates.	*Chairman.*—Professor W. A. Osborne. *Secretary.*—Miss Kincaid. Dr. Rothera.
The Dissociation of Oxy-Hæmoglobin at High Altitudes.	*Chairman* —Professor E. H. Starling. *Secretary.*—Dr. J. Barcroft. Dr. W. B. Hardy.
Colour Vision and Colour Blindness.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Dr. Edridge-Green Professor A. W. Porter, Dr. A. D. Waller, Professor C. S. Sherrington, and Dr F. W Mott.
Calorimetric Observations on Man in Health and in Febrile Conditions.	*Chairman.*—Professor J. S. Macdonald. *Secretary.*—Dr. Francis A. Duffield. Dr. Keith Lucas.
The Binocular Combination of Kinematograph Pictures of different Meaning, and its relation to the Binocular Combination of simpler Perceptions.	*Chairman.*—Dr. C. S Myers. *Secretary.*— Mr. T. H. Pear.
SECTION K.—BOTANY.	
To carry out a Research on the Influence of varying percentages of Oxygen and of various Atmospheric Pressures upon Geotropic and Heliotropic Irritability and Curvature.	*Chairman.*—Professor F. O. Bower. *Secretary.*—Professor A. J. Ewart. Professor F. F. Blackman.
The Collection and Investigation of Material of Australian Cycadaceæ, especially Bowenia from Queensland and Macrozaunia from West Australia.	*Chairman.*—Professor A. A. Lawson. *Secretary.*—Professor T. G. B. Osborn. Professor A. C. Seward.
To cut Sections of Australian Fossil Plants, with especial reference to a specimen of Zygopteris from Simpson's Station, Barraba, N.S.W.	*Chairman.*—Professor Lang. *Secretary.*—Professor T. G. B. Osborn. Professor T. W. E. David and Professor A. C. Seward.
The Investigation of the Vegetation of Ditcham Park, Hampshire.	*Chairman.*—Mr A. G. Tansley. *Secretary.*—Mr. R S. Adamson. Dr. C. E. Moss and Professor R. H. Yapp.
SECTION L.—EDUCATIONAL SCIENCE.	
To take notice of, and report upon changes in, Regulations—whether Legislative, Administrative, or made by Local Authorities — affecting Secondary and Higher Education.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Major E. Gray. Miss Coignan, Principal Griffiths, Dr. C. W. Kimmins, Sir Horace Plunkett, Mr. H. Ramage, Professor M. E. Sadler, and Rt. Rev. J. E. C. Welldon.

Communications ordered to be printed in extenso.

Section A.—Mr. G. Hardy: On Prime Numbers.
Section B.—Discussion on Smoke Prevention.
Section B.—Discussion on Homogeneous Catalysis

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

From Section A.

That the Committee of Section A places upon record its high appreciation of the assistance rendered to the investigation of the value of gravity at sea by the Directors of Messrs. Alfred Holt, of Liverpool, during the voyage of the British Association to Australia in 1914. The Association is indebted to them for the generous installation of a special refrigerating chamber for the purpose of this research, and for placing at the disposal of the experimenter (Dr Duffield) the whole of the resources of the Blue Funnel steamship *Ascanius*; in this respect the help of Captain Chrimes, Chief Engineer Douglas, and Refrigerating Engineer Latham deserves particular mention.

The Association regrets that the outbreak of war prevented full advantage being taken of the facilities so kindly made available by Messrs. Alfred Holt, but it is none the less grateful for their valuable and whole-hearted co-operation.

That a copy of the above Resolution be forwarded to Messrs. Alfred Holt.

From Section B.

To recommend to the Council that the proceedings of Section B, together with the reports of research committees, including any reports on special branches of chemical science, be published separately from the Annual Volume of Reports.

At its meeting on September 9, the General Committee unanimously adopted the following resolution, and ordered that it should be forwarded to the Prime Minister, the Chancellor of the Exchequer, and the Presidents of the Boards of Education and of Agriculture and Fisheries:—

That the British Association for the Advancement of Science, believing that the higher education of the nation is of supreme importance in the present crisis of our history, trusts that His Majesty's Government will, by continuing its financial support, maintain the efficiency of teaching and research in the Universities and University Colleges of the United Kingdom.

Synopsis of Grants of Money appropriated for Scientific Purposes on behalf of the General Committee at the Manchester Meeting, September 1915. *The Names of Members entitled to call on the General Treasurer for Grants are prefixed to the respective Committees.*

Section A.—Mathematical and Physical Science.

	£	s.	d.
*Turner, Professor H. H.—Seismological Observations	130	0	0
*Ramsay, Sir W.—Tables of Constants	40	0	0
*Hill, Professor M. J. M.—Mathematical Tables	35	0	0
Carried forward	£205	0	0

* Reappointed.

	£	s.	d.
Brought forward	205	0	0
Section B.—Chemistry.			
*Armstrong, Professor H. E.—Dynamic Isomerism	20	0	0
*Kipping, Professor F. S.—Aromatic Nitroamines	10	0	0
*Hall, Mr. A. D.—Plant Enzymes	10	0	0
*Armstrong, Professor H. E.—Solubility Phenomena	5	0	0
*Armstrong, Professor H. E.—Eucalypts	30	0	0
*Masson, Professor Orme.—Influence of Weather Conditions on Nitrogen Acids in Rainfall and Atmosphere	20	0	0
*Pope, Professor W. J.—Crystalline Form and Molecular Structure	10	0	0
*Chattaway, Dr. F. D.—Non-aromatic Diazonium Salts	8	10	0
Dobbie, Sir J. J.—Absorption Spectra, &c.	10	0	0
Section C.—Geology.			
*Cole, Professor Grenville.—Old Red Sandstone Rocks of Kiltorcan	7	0	0
*Watts, Professor W. W.—Critical Sections in Palæozoic Rocks	20	0	0
*Kendall, Professor P. F.—List of Characteristic Fossils	10	0	0
Horne, Dr. J.—Old Red Sandstone Rocks at Rhynie	25	0	0
Kidston, Dr. R.—Lower Carboniferous Flora at Gullane	8	0	0
Section D.—Zoology.			
*Shipley, Dr. A. E.—Belmullet Whaling Station	25	0	0
Section E.—Geography.			
*Lucas, Sir C. P.—Conditions determining Selection of Sites and Names for Towns	15	0	0
Section F.—Economic Science and Statistics.			
*Muirhead, Professor J. H.—Fatigue from Economic Standpoint	40	0	0
Kirkaldy, Professor A. W.—Industrial Unrest	20	0	0
Scott, Professor W. R.—Women in Industry	90	0	0
Scott, Professor W. R.—Effects of War on Credit, &c.	25	0	0
Section G.—Engineering.			
*Perry, Professor J.—Complex Stress Distributions	40	0	0
*Clerk, Dr. Dugald.—Gaseous Explosions	50	0	0
Hele-Shaw, Dr. H. S.—Engineering Problems affecting Prosperity of the Country	10	0	0
Section H.—Anthropology.			
*Read, Sir C. H.—Age of Stone Circles	25	0	0
*Smith, Professor G. Elliot.—Physical Characters of Ancient Egyptians	15	0	0
*Marett, Dr. R. R.—Palæolithic Site in Jersey	25	0	0
*Myres, Professor J. L.—Archæological Investigations in Malta	10	0	0
*Myres, Professor J. L.—Distribution of Bronze Age Implements	5	0	0
Carried forward	£793	10	0

	£	s.	d.
Brought forward	793	10	0
Section I.—Physiology.			
*Schäfer, Sir E.—Ductless Glands	20	0	0
*Sherrington, Professor C. S.—Mammalian Heart	20	0	0
Section K.—Botany.			
*Bower, Professor F. O.—Cinchona Station, Jamaica	12	10	0
*Oliver, Professor F. W.—Structure of Fossil Plants	2	0	0
*Blackman, Professor F. F.—Heredity	45	0	0
Section L.—Education.			
*Green, Professor J. A.—Museums	15	0	0
*Auden, Dr. G. A.—School Books and Eyesight	5	0	0
*Myers, Dr. C. S.—Mental and Physical Factors	20	0	0
Buckmaster, Mr. C. A.—'Free-place' System	10	0	0
Corresponding Societies Committee.			
*Whitaker, Mr. W.—For Preparation of Report	25	0	0
Total	£968	0	0

* Reappointed.

CAIRD FUND.

An unconditional gift of 10,000*l.* was made to the Association at the Dundee Meeting, 1912, by Mr. (afterwards Sir) J. K. Caird, LL.D., of Dundee.

The Council in its Report to the General Committee at the Birmingham Meeting made certain recommendations as to the administration of this Fund. These recommendations were adopted, with the Report, by the General Committee at its meeting on September 10, 1913.

The following allocations have been made from the Fund by the Council to September 1915 :—

Naples Zoological Station Committee (p. lxi).—50*l.* (1912-13); 100*l.* (1913-14); 100*l.* annually in future, subject to the adoption of the Committee's report.

Seismology Committee (p. lii).—100*l.* (1913-14); 100*l.* annually in future, subject to the adoption of the Committee's report.

Radiotelegraphic Committee (p. lx). 500*l.* (1913-14).

Magnetic Re-survey of the British Isles (in collaboration with the Royal Society).—250*l.*

Committee on Determination of Gravity at Sea (p. lx).—100*l.* (1914-15).

Mr. F. Sargent, Bristol University, in connection with his Astronomical Work.—10*l.* (1914).

Organising Committee of Section F (Economics), towards expenses of an Enquiry into Outlets for Labour after the War.—100*l.* (1915).

Sir J. K. Caird, on September 10, 1913, made a further gift of 1,000*l.* to the Association, to be devoted to the study of Radio-activity.

Public or Citizens' Lectures.

During the Meeting the following Citizens' Lectures were arranged in co-operation with the local branches of the Workers' Educational Association in Manchester and the neighbourhood:—

Manchester.

September 8th at 8 p.m. in the New Islington Hall, Ancoats, Professor F. W. Gamble, F.R.S., on 'Evolution and War.'

September 9th at 8 p.m. in the Central Hall, Oldham Street, Dr. Vaughan Cornish on 'The Strategic Geography of the War.'

September 10th at 8 p.m. in the Albert Hall, Peter Street, Dr. Walter Rosenhain, F.R.S., on 'The Making of a Big Gun.'

Salford.

September 9th at 8 p.m. in the Royal Technical Institute, Salford, Dr. Walter Rosenhain, F.R.S., on 'The Making of a Big Gun.'

September 10th at 8 p.m. in the Royal Technical Institute, Salford, Professor W. Stirling on 'Curiosities and Defects of Sight.'

Oldham.

September 9th at 8 p.m. in the Equitable Co-operative Hall, Mr. A. R. Hinks, F.R.S., on the 'Daily Uses of Astronomy.'

September 11th at 8 p.m. in the Industrial Co-operative Hall, Professor Benjamin Moore, F.R.S., on 'Health Conditions in the Modern Workshop.'

Bolton.

September 10th at 8 p.m. in the Victoria Hall, Rev. A. L. Cortie, S.J., on 'Formation of the Sun and Stars.'

Rochdale.

September 6th at 8 p.m. in the Town Hall, Professor H. H. Turner, F.R.S., on 'Some Lessons from Astronomy.'

PRESIDENT'S ADDRESS.

ADDRESS

BY

PROFESSOR ARTHUR SCHUSTER, D.Sc., Sc.D., LL.D., DR. ÈS SC., F.R.S.
PRESIDENT.

The Common Aims of Science and Humanity.

UNDER the influence of the diversity of pursuits imposed upon us by the conditions of modern life, different groups of the community—men of business, men of science, philosophers, or artists—have acquired detached and sometimes conflicting interests. Each group, impressed by the importance of its own domain in the life of the nation, and focussing its vision on small differences and temporary rivalries, was in danger of losing the sense of mutual dependence. But in the shadow of a great catastrophe it has been brought home to us that the clash of interests is superficial, and the slender thread of union which remained has grown into a solid bond. What is the fibre from which the bond is twined? Patriotism may express its outward manifestation, but its staple is the mental relationship which remains continuous and dominant even in normal times, when each of us may peacefully go to earn his living and enjoy the course of his intellectual life.

Outwardly the community is divided into heterogeneous elements with mental attitudes cast in different moulds, and proceeding along separate roads by differing methods to different ideals. Yet as we eliminate the superficial, and regard only the deep-seated emotions which control our thoughts and actions, the differences vanish, and the unity of purpose and sentiment emerges more and more strongly. Mind and character, no doubt, group themselves into a number of types, but the cleavage runs across, and not along, the separating line of professions.

Were it otherwise, the British Association could not perform one of its most important functions—a function not, indeed, originally contemplated, but resulting indirectly from the wise and democratic provisions in its constitution, which enabled it to adapt itself to the changing needs of the time. Our founders primarily considered the interests of scientific men; their outlook was restricted and exclusive, both as regards range

of subject and membership. In the words of Sir David Brewster, who gave the first impulse to its formation, it was to be 'an Association of our nobility, clergy, gentry, and philosophers.'

The meetings were intended to promote personal intercourse, to organise research, to advocate reform of the laws hindering research, and to improve the status of scientific men. The right of membership was confined to those who already belonged to some learned society, and William Whewell, one of the principal supporters of the movement, even suggested that only authors of memoirs published by a learned society should be admitted.[1] He emphasized this proposal by the recommendation[2] 'in some way to avoid the crowd of lay members whose names stand on the List of the Royal Society.' The reform of the Patent Laws and the introduction of an International Copyright were suggested as subjects suitable for discussion, not apparently from the point of view of general advantage, but merely in the interests of one section of the community.

Whatever the objects of the founders of the Association may have been, it is obvious that questions of public importance could not be permanently excluded from meetings the success of which depended on the interest stimulated in the community. The Statistical Section, which owed its origin to the visit, at the first Oxford Meeting (1832), of Quetelet, the Belgian astronomer and economist, was the first to assert itself by engaging in a discussion of the Poor Laws. Whewell deeply resented this violation of academic neutrality: 'it was impossible,' he wrote, 'to listen to the Proceedings of the Statistical Section on Friday without perceiving that they involved exactly what it was most necessary and most desired to exclude from our Proceedings,'[3] and again: 'Who would propose (I put it to Chalmers, and he allowed the proposal to be intolerable) an ambulatory body, composed partly of men of reputation and partly of a miscellaneous crowd, to go round year by year from town to town and at each place to discuss the most inflammatory and agitating questions of the day?'[4]

Fortunately for our Association, this narrow-minded attitude did not prevail, and our records show that while not avoiding controversial and even inflammatory subjects, we have been able to exercise a powerful influence on the progress of science. The establishment of electric units, universally accepted throughout the world, originated in the work of one of our committees; the effort which led to the foundation of the National Physical Laboratory, one of the most efficient and beneficial

[1] Others were allowed to join on recommendation by the General Committee. It was only in 1906 that this restriction, which had become obsolete, was removed.

[2] *Whewell's Writings and Letters*, vol. ii. p. 128.

[3] *Loc. cit.*, p. 289.

[4] It is much to be desired that the documents relating to the early history of the British Association should be published in a collected form.

organizations in the country, received its first impulses from us; and the organization of the first world service for the systematic investigation of earth tremors was established by the late Dr. Milne, working through one of our Committees.

The success of these enterprises alone is sufficient to show that we are not merely a body promoting social intercourse between men of science and the rest of the community. Nevertheless, it may be admitted that our efforts have been spasmodic, and the time has arrived to consider whether it may be possible to secure not only a greater continuity in our work but also its better co-ordination with that of other scientific organizations. The present juncture affords the opportunity, and the changed conditions, which in the near future will affect all our institutions, render it indeed incumbent upon us once more to adapt ourselves to the needs of the times. Proposals for a move in that direction have already been made, and will no doubt be carefully considered by the Council. In the meantime, I may draw your attention to the important discussions arranged for by our Economic Section, which alone will justify the decision of the Council not to suspend the Meeting this year.

It must not be supposed that, even in the early days of the Association, Whewell's ideas of its functions were universally accepted. It is pleasant to contrast the lamentations of the omniscient Professor of Mineralogy with the weightier opinion of the distinguished mathematician who then held Newton's chair at Cambridge. At the concluding session of the second meeting of the Association Babbage expressed the hope 'that in the selection of the places at which the annual meetings were to be held, attention should be paid to the object of bringing theoretical science in contact with the practical knowledge on which the wealth of the country depends.' 'I was myself,' he said, 'particularly anxious for this, owing as I do a debt of gratitude for the valuable information which I have received in many of the manufacturing districts, where I have learned to appreciate still more highly than before the value of those speculative pursuits which we follow in our academical labours. I was one of those who thought at first that we ought to adjourn for our next meeting to some large manufacturing town; but I am now satisfied that the arrangement which has been made will be best adapted to the present state of the Association. When, however, it shall be completely consolidated I trust we may be enabled to cultivate with the commercial interests of the country that close acquaintance which I am confident will be highly advantageous to our more abstract pursuits.'

Since then, as we all know, our most successful meetings have been held in manufacturing centres; but it should be observed that,

while Babbage laid stress on the benefit which would accrue to pure science by being brought into contact with practical life, scientific men of the present day have more and more insisted on the services they, on their part, are able to render to the industries. The idealistic motive has thus given way to the materialistic purpose. Both aspects are perhaps equally important, but it is necessary to insist, at the present time, that the utilitarian drum can be beaten too loudly. There is more than one point of contact between different activities of the human mind, such as find expression in scientific pursuits or commercial enterprises, and it is wrong to base the advantages to be derived from their mutual influence solely, or even mainly, on the ground of material benefits.

I need not press this point in a city which has given many proofs that a business community may be prompted by higher motives than those which affect their pockets. It was not for utilitarian objects that repeated efforts were made since the year 1640 to establish a University in Manchester; it was not for reasons of material gain that the Royal Institution and Owens College were founded; nor was it because they increased the wealth of the district that the place of honour in our Town Hall has been given to Dalton and Joule.

When we glance at the various occupations of the working parts of a nation, comprising the student who accumulates or extends knowledge, the engineer who applies that knowledge, the geologist or agriculturalist who discloses the store of wealth hidden in the soil, the commercial man who distributes that wealth, it seems as if we ought to be able to name the qualities of intellect and temperament which in each pursuit are most needed to carry out the work successfully. But on trying to define these qualities we soon discover the formidable nature of the task. Reasoning power, inventive power, and sound balance of judgment are essential attributes in all cases, and the problem is reduced to the question whether there are different varieties of these attributes which can be assigned to the different occupations.

Among all subjects mathematics is perhaps the one that appears most definitely to require a special and uncommon faculty. Yet, Poincaré—himself one of the clearest thinkers and most brilliant exponents of the subject—almost failed when he attempted to fix the distinguishing intellectual quality of the mathematician. Starting from the incontrovertible proposition that there is only one kind of correct reasoning, which is logical reasoning, he raises the question why it is that everybody who is capable of reasoning correctly is not also a mathematician, and he is led to the conclusion that the characterizing feature is a peculiar type of memory. It is not a better memory, for some mathematicians are very forgetful, and many of them cannot add

a column of figures correctly; but it is a memory which fixes the order in which the successive steps of reasoning follow each other without necessarily retaining the details of the individual steps. This Poincaré illustrates by contrasting the memory of a chess-player with that of a mathematician. 'When I play chess,' he says, 'I reason out correctly that if I were to make a certain move, I should expose myself to a certain danger. I should, therefore, consider a number of other moves, and, after rejecting each of them in turn, I should end by making the one which I first contemplated and dismissed, having forgotten in the meantime the ground on which I had abandoned it.' 'Why, then,' he continues, 'does my memory not fail me in a difficult mathematical reasoning in which the majority of chess-players would be entirely lost? It is because a mathematical demonstration is not a juxtaposition of syllogisms, but consists of syllogisms placed in a certain order; and the order in which its elements are placed is much more important than the elements themselves. If I have this intuition—so to speak—of the order, so as to perceive at one glance the whole of the reasoning, I need not fear to forget its elements: each of these will take its right place of its own accord without making any call on my memory.'[5]

Poincaré next discusses the nature of the intellectual gift distinguishing those who can enrich knowledge with new and fertile ideas of discovery. Mathematical invention, according to him, does not consist in forming new combinations of known mathematical entities, because the number of combinations one could form are infinite, and most of them would possess no interest whatever. Inventing consists, on the contrary, in excluding useless combinations, and therefore: 'To invent is to select—to choose.' . . . 'The expression "choose" perhaps requires qualifying, because it recalls a buyer to whom one offers a large number of samples which he examines before making his choice. In our case the samples would be so numerous that a lifetime would not suffice to complete the examination. That is not the way things are done. The sterile combinations do not even present themselves to the mind of the inventor, and those which may momentarily enter his consciousness, only to be rejected, partake something of the character of useful combinations. The inventor is therefore to be compared with an examiner who has only to deal with candidates who have already passed a previous test of competence.'

All those who have attempted to add something to knowledge must recognize that there is a profound truth in these remarks. New ideas may float across our consciousness, but, selecting the wrong ones for more detailed study, we waste our time fruitlessly. We are bewildered by the multitude of roads which open out before us, and, like Poincaré

[5] *Science et Méthode*, pp. 46 and 47.

when he tries to play chess, lose the game because we make the wrong move. Do we not all remember how, after the announcement of a new fact or generalization, there are always many who claim to have had, and perhaps vaguely expressed, the same idea? They put it down to bad luck that they have not pursued it, but they have failed precisely in what, according to Poincaré, is the essence of inventive power. It may be bad luck not to have had a good idea, but to have had it and failed to appreciate its importance is downright incapacity.

An objection may be raised on the ground that before a selection can be made the ideas themselves must appear, and that, even should they arrive in sufficient numbers, the right one may not be among them. It may even be argued that Poincaré gives his case away by saying that 'the sterile combinations do not even present themselves to the mind of the inventor,' expressing in a negative form what may be the essence of the matter. Moreover, a fertile mind like that of Poincaré would be apt to place too low a value on his own exceptional gifts. Nevertheless, if Poincaré's more detailed exposition be read attentively, and more especially the description of how the discoveries which made him famous among mathematicians originated in his mind, it will be found that his judgment is well considered and should not be lightly set aside. New ideas seldom are born out of nothing. They most frequently are based on analogies, or the recollection of a sequence of thoughts suggested by a different branch of the subject, or perhaps by a different subject altogether. It is here that the memory comes in, which is not a memory of detail, but a memory of premises with their conclusions, detached from the particular case to which they were originally applied. Before we pronounce an adverse opinion on Poincaré's judgment, we must therefore investigate what constitutes novelty in a new idea; but the subject is too vast to be dealt with here, nor can I attempt to discuss whether an essential distinction exists between mathematical invention and that more practical form of invention with which, for instance, the engineer has to deal.

If Poincaré, by this introspective analysis of his own powers, has dimmed the aureole which, in the eyes of the public, surrounds the mathematician's head, he removes it altogether by his definition of mathematics. According to him, 'mathematics is the art of calling two different things by the same name.' It would take me too far were I to try to explain the deep truth expressed in this apparently flippant form: physicists, at any rate, will remember the revolution created in the fundamental outlook of science by the application of the term 'energy' to the two quite distinct conceptions involved in its subdivisions into potential and kinetic energy.

Enough has been said to show that the peculiar powers necessary

for the study of one of the most abstruse branches of knowledge may be expressed in terms which bring them down to the level at which comparison with other subjects is possible. Applying the same reasoning to other occupations, the same conclusion is inevitable. The commercial man, the politician, and the artist must all possess the type of memory best suited to concentrate in the field of mental vision their own experiences as well as what they have learned from the experience of others; and, further, they must have the power of selecting out of a multitude of possible lines of action the one that leads to success: it is this power which Poincaré calls the inventive faculty.

The argument must not be pushed too far, as it would be absurd to affirm that all differences in the capability of dealing successfully with the peculiar problems that occur in the various professions may be reduced to peculiarities of memory. I do not even wish to assert that Poincaré's conclusions should be accepted without qualification in the special case discussed by him. What is essential, to my mind, is to treat the question seriously, and to dismiss the vague generalities which, by drawing an artificial barrier between different groups of professions, try to cure real or imaginary defects through plausible though quite illusory remedies. All these recommendations are based on the fallacy that special gifts are associated with different occupations. Sometimes we are recommended to hand over the affairs of the nation to men of business; sometimes we are told that salvation can only be found in scientific methods—what is a man of business, and what is a scientific method? If you define a man of business to be one capable of managing large and complicated transactions, the inference becomes self-evident; but if it be asserted that only the specialized training in commercial transactions can develop the requisite faculties, the only proof of the claim that could be valid would be the one that would show that the great majority of successful statesmen, or political leaders, owed their success to their commercial experience. On the other hand, every method that leads to a correct result must be called a scientific method, and what requires substantiating is that scientific training is better than other training for discovering the correct method. This proof, as well as the other, has not been, and, I think, cannot be, given. When, therefore, one man calls for the conduct of affairs 'on business lines' and the other clamours for scientific methods, they either want the same thing or they talk nonsense. The weak point of these assertions contrasting different classes of human efforts is that each class selects its own strongest men for comparison with the weakest on the other side. Where technical knowledge is required, the specialist should be consulted, but in questions of general policy he is seldom the best guide.

The most fatal distinction that can be made is the one which brings

men of theory into opposition to men of practice, without regard to the obvious truth that nothing of value is ever done which does not involve both theory and practice. While theory is sometimes overbearing and irritating, there are among those who jeer at it, at any rate, a few to whom Disraeli's definition applies: the practical man is the man who practises the errors of his forefathers. With refined cruelty Nemesis infects us with the disease most nearly akin to that which it pleases us to detect in others. It is the most dogmatic of dogmatics who tirades against dogma, and only the most hopeless of theorists can declare that a thing may be right in theory and wrong in practice.

Why does a theory ever fail, though it may be sound in reasoning? It can only do so because every problem involves a much larger number of conditions than those which the investigator can take into account. He therefore rejects those which he believes to be unessential, and if his judgment is at fault he goes wrong. But the practical man will often fail for the same reason. When not supported by theoretical knowledge he generalizes the result of an observation or experiment, applying it to cases where the result is determined by an altogether different set of conditions. To be infallible the theorist would have to take account of an infinite number of circumstances, and his calculations would become unmanageable, while the experimenter would have to perform an infinite number of experiments, and both would only be able to draw correct conclusions after an infinite lapse of time. They have to trust their intuition in selecting what can be omitted with impunity, and, if they fail, it is mainly due to the same defect of judgment. And so it is in all professions: failure results from the omission of essential considerations which change the venue of the problem.

Though theory and practice can only come into opposition when one of them is at fault, there is undoubtedly a contrast of character and temperament between those who incline more towards the one and those who prefer the other aspect: some like a solitary life at the desk, while others enjoy being brought into contact with their fellows. There have at all times been men predestined by nature to be leaders, and leadership is required in all branches of knowledge—the theoretical as well as the more active pursuits; but we must distrust a man's own estimate of his power to convert his thoughts into acts. In the ordinary affairs of life a man who calls himself a man of action is frequently only one who cannot give any reasons for his actions. To claim that title justly a man must act deliberately, have confidence in his own judgment, sufficient tenacity of purpose to carry it through, and sufficient courage to run the unavoidable risks of possible failure. These risks may be trivial or they may be all-important. They may

affect the reputation of one unit of creation or involve the whole life of a nation, and according to the greatness of the issue we shall honour the man who, having taken the risk, succeeds. But whether the scale be microscopic or interstellar, the essence of the faculty of blending theory and practice is the same, and both men of books and men of action are to be found in the philosopher's study and the laboratory, as well as in the workshop or on the battlefield. Modern science began, not at the date of this or that discovery, but on the day when Galileo decided to publish his Dialogues in the language of his nation. This was a deliberate act destined to change the whole aspect of science, which, ceasing to be the occupation of a privileged class, became the property of the community. Can you, therefore, deny the claim of being a man of action to Galileo, can you deny it to Pasteur, Kelvin, Lister, and a host of others? There are, no doubt, philosophers who cannot manage even their own affairs, and whom it would be correct to call pure theorists, but that proves nothing, because their defect makes them worse philosophers as well as worse citizens.

In his Presidential Address, delivered to this Association in 1899, Sir Michael Foster summarized the essential features of the scientific mind. Above all other things he considered that its nature should be such as to vibrate in unison with what it is in search of; further, it must possess alertness, and finally moral courage. Yet after enumerating these qualities, he arrives at the same result which I have tried to place before you, that there are no special peculiarities inherent in the scientific mind, and he expresses this conclusion in the following words:

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

This saying of Huxley's has been repeated so often that one almost wishes it were true, but unfortunately I cannot find a definition of common-sense that fits the phrase. Sometimes the word is used as if it were identical with *uncommon* sense, sometimes as if it were the same thing as common *nonsense*. Often it means untrained intelligence, and in its best aspect it is, I think, that faculty which recognizes that the obvious solution of a problem is frequently the right one. When, for instance, I see, during a total solar eclipse, red flames shooting out from the edge of the sun, the obvious explanation is that

these are real phenomena caused by masses of glowing vapours ejected from the sun; and when a learned friend tells me that all this is an optical illusion due to anomalous refraction, I object on the ground that the explanation violates my common-sense. He replies by giving me the reasons which have led him to his conclusions, and, though I still believe that I am right, I have to meet him with a more substantial reply than an appeal to my own convictions. Against a solid argument common-sense has no power and must remain a useful but fallible guide which both leads and misleads all classes of the community alike.[6]

The difficulties of assigning special intellectual qualities to groups of men within one country are increased when we compare different nations with each other. Some of the so-called national, or more properly speaking racial, characteristics are undoubtedly regulated by the laws of heredity, but there are many others which seem to depend entirely on education and training; and, if I select one as an example, it is because it figures so largely in public discussions at the present moment. I refer to that expedient for combining individual efforts which goes by the name of organization. An efficient organization requires a head that directs and a body that obeys; it works mainly through discipline, which is its most essential attribute. Every institution, every factory, every business establishment is a complicated organism, and no country ever came to prominence in any walk of life unless it possessed the ability to provide for the efficient working of such organisms. To say that a nation which has acquired and maintained an Empire, and which conducts a large trade in every part of the world, is deficient in organizing power is therefore an absurdity. Much of the current self-depreciation in this respect is due to confusing a true organization with that modification of it which to a great extent casts aside discipline and substitutes co-operation. Though much may be accomplished by co-operation, it is full of danger in an emergency, for it can only work if it be loyally adhered to; otherwise it resembles a six-cylinder motor in which every sparking-plug is allowed to fix its own time of firing. Things go well so long as the plugs agree; but there is nearly always one among them that persists in taking an independent course and, when the machine stops, complains that the driver is inefficient. The cry for organization, justifiable as it no doubt often is, resolves itself, therefore, into a cry for increased discipline, by which I do not mean the discipline enforced at the point of the bayonet, but that accepted by the individual who voluntarily subor-

[6] Since writing the above, I find on reading Professor J. A. Thomson's 'Introduction to Science' a similar criticism of Huxley's dictum. Prof. Thomson's general conclusions are not, however, in agreement with those here advocated.

dinates his personal convictions to the will of a properly constituted authority. This discipline is not an inborn quality which belongs more to one nation than to another; it is acquired by education and training. In an emergency it is essential to success, but if it be made the guiding principle of a nation's activity, it carries dangers with it which are greater than the benefits conferred by the increased facility for advance in some directions.

If there be no fundamental difference in the mental qualifications which lead to success in our different occupations, there is also none in the ideals which move us in childhood, maintain us through the difficulties of our manhood, and give us peace in old age. I am not speaking now of those ideals which may simultaneously incite a whole nation to combined action through religious fervour or ambition of power, but I am speaking of those more individual ideals which make us choose our professions and give us pleasure in the performance of our duties.

Why does a scientific man find satisfaction in studying Nature?

Let me once more quote Poincaré [7]:—

'The student does not study Nature because that study is useful, but because it gives him pleasure, and it gives him pleasure because Nature is beautiful; if it were not beautiful it would not be worth knowing and life would not be worth living. I am not speaking, be it understood, of the beauty of its outward appearance; not that I despise it—far from it—but it has nothing to do with science: I mean that more intimate beauty which depends on the harmony in the order of the component parts of Nature. This is the beauty which a pure intelligence can appreciate and which gives substance and form to the scintillating impressions that charm our senses. Without this intellectual support the beauty of the fugitive dreams inspired by sensual impressions could only be imperfect, because it would be indecisive and always vanishing. It is this intellectual and self-sufficing beauty, perhaps more than the future welfare of humanity, that impels the scientific man to condemn himself to long and tedious studies. And the same search for the sense of harmony in the world leads us to select the facts which can most suitably enhance it, just as the artist chooses among the features of his model those that make the portrait and give it character and life. There need be no fear that this instinctive and unconscious motive should tempt the man of science away from the truth, for the real world is far more beautiful than any vision of his dreams. The greatest artists that ever lived—the Greeks—constructed a heaven; yet how paltry that heaven is compared to ours! And it is because simplicity and grandeur are beautiful that we select

[7] *Loc. cit.* p. 15.

by preference the simplest and grandest facts, and find our highest pleasure, sometimes in following the gigantic orbits of the stars, sometimes in the microscopic study of that minuteness which also is a grandeur, and sometimes in piercing the secrets of geological times which attract us because they are remote. And we see that the cult of the beautiful guides us to the same goal as the study of the useful.'

'Whence comes this harmony? Is it that things that appear to us as beautiful are simply those which adapt themselves best to our intelligence, and are therefore the tools which that intelligence handles most easily; or is it all the play of evolution and natural selection? In that case, those races only survived whose ideals best conformed with their interests, and while all nations pursued their ideals without regard to consequences, some were led to perdition and others achieved an empire. One is tempted to believe that such has been the course of history, and that the Greeks triumphed over the barbarians, and Europe, inheritor of Greek thought, rules the world, because the savages cared only for the sensual enjoyment of garish colours and the blatant noise of the drum, while the Greeks loved the intellectual beauty which is hidden beneath the visible beauty. It is that higher beauty which produces a clear and strong intelligence.' If the mathematician's imagination is fired by the beauty and symmetry of his methods, if the moving spring of his action is identical with that of the artist, how much truer is this of the man of science who tries by well-designed experiments to reveal the hidden harmonies of Nature? Nor would it be difficult, I think, to trace the gratification inherent in the successful accomplishments of other intellectual pursuits to the same source.

Though Poincaré was, I believe, the first to lay stress on the connexion between the search for the beautiful and the achievement of the useful, the æsthetic value of the study of science had previously been pointed out, and well illustrated, by Karl Pearson in his 'Grammar of Science.' As expressed by him: 'it is this continual gratification of the æsthetic judgment which is one of the chief delights of pure science.' Before we advance, however, any special claim for the pursuit of science based on these considerations, we must pause to think whether they do not equally apply to other studies or occupations. For this purpose, the nature of the æsthetic enjoyment involved must be remembered. We do not mean by it, the pleasure we feel in the mere contemplation of an impressive landscape or natural beauty, but rather the enjoyment experienced on looking at a picture which, independently of what it may be trying to imitate, has a definite beauty due to its contrast of colours or well-balanced arrangement. We have in one case a number of pigments covering a space of two dimensions, and in

the other the natural object in three dimensions made up of entirely different materials and showing an infinite variety of detail and appearance. By itself alone either a mere photographic reproduction, or a geometrical arrangement of colour and line, leaves most of us cold; though both have their own particular beauty, the art consists in bringing them into connexion. Bearing in mind the æsthetic value of the relationship of the work of our brain or hand to external facts or appearances, it might easily be shown that what has been said of science equally applies to other studies, such as history or literature. We may even go further, and say that any occupation whatever, from which we can derive an intellectual pleasure, must possess to a greater or smaller degree the elements of combining the useful with the beautiful.

In order to trace in detail the part played by purely emotional instincts in directing the course of our lives, we should have to study the causes which influence a child, free to select his future profession. Having eliminated secondary effects, such as early associations, or the personal influence of an inspiring teacher, we should probably be brought to a standstill by the dearth of material at our disposal, or led into error by taking our own individual recollections as typical. Nevertheless it is only through the record of each man's experience that we may hope to arrive at a result. If every man who has reached a certain recognized position in his own subject—it need not be pre-eminence—would write down his recollections of what led him to make the choice of his profession, we might hope to obtain facts on which a useful psychological study might be based. Scientific men as a class are not modest, but they share with other classes the reluctance to speak of their early life, owing to a certain shyness to disclose early ambitions which have not been realized. It requires courage to overcome that shyness, but I think that we need feel no shame in revealing the dreams of our childhood and holding fast to them despite the bondage of our weakness, despite the strife ending so often in defeat, despite all the obstacles which the struggle for existence has placed in our path. In some form they should persist throughout our lives and sustain us in our old age.

But the account of our early life should be simple, detached from any motives of self-depreciation or self-assertion, and free from any desire to push any particular moral or psychological theory. We want to trace the dawn of ambition, the first glimmering in the child's mind that there is something that he can do better than his fellows, and reminiscences of early likes and dislikes which, though apparently disconnected from maturer tendencies, may serve as indications of a deep-seated purpose in life. It may be difficult to resist the temptation

of trying to justify one's reputation in the eyes of the world; but it is worth making the effort. The only example that I know of such an autobiographical sketch is that of Darwin, which is contained in his 'Life and Letters,' published by his son, Sir Francis Darwin.

The ambition of a child to be better, cleverer, or more beautiful than its fellows is in the main, I think, a wish to please and to be praised. As the child grows up, the ambition becomes more definite. It is not a sordid ambition for ultimate wealth or power, nor is it an altruistic ambition to do good for the sake of doing good. Occasionally it takes the form confessed to by Darwin, when he says: 'As a child I was much given to inventing deliberate falsehoods, and this was always done for the sake of causing excitement.' This desire to be conspicuous was, in Darwin's case, consistent with extreme modesty, amounting almost to a want of confidence in himself, as appears in this passage: 'I remember one of my sporting friends, Turner, who saw me at work with my beetles, saying that I should some day be a Fellow of the Royal Society, and this notion seemed to me to be preposterous.'

We next come to the stage where a child is attracted by one subject more than another, and, if his choice be free, will select it for his life's career. What guides him in this choice? If it be said that a boy gravitates towards that subject which he finds easiest, we are led to the further question why does he find it easiest? It is on this point that more information is required, but I am inclined to answer in accordance with Poincaré's views that it is because its particular beauty appeals most strongly to his emotional senses. In questions of this kind everyone must form his own conclusions according to his personal recollections, and these convince me that the emotional factor appears already at an early age. It is the strong attraction towards particular forms of reasoning, more perhaps even than the facility with which reasoning comes, that carries us over the initial difficulties and the drudgery that must accompany every serious study.

I have already alluded to the different tendencies of individuals either to prefer solitary reflexion or to seek companionship. Almost in every profession we find men of both types. Darwin's autobiography furnishes a good example of the man who prefers to learn through quiet reading rather than through lectures, but to many men of science the spoken word is inspiring and contact with congenial minds almost a necessity.

From our present point of view the most interesting passages in Darwin's autobiography are those indicating the æsthetic feeling which, like Poincaré, he connects with scientific research. Referring to his early studies we find this passage: 'I was taught by a private tutor

and I distinctly remember the intense satisfaction which the clear geometrical proofs gave me. I remember with equal distinctness the delight which my uncle gave me by explaining the principle of the vernier of a barometer.' To a man who apparently had no pronounced facility of mastering mathematical difficulties this feeling of satisfaction is especially remarkable. The combination of scientific ability with leanings either to music, or art, or poetry, is very common, and examples are to be found in almost every biography of men of science. It is difficult indeed to name an eminent scientific man who has not strong leanings towards some artistic recreation: we find the poetic vein in Maxwell and Sylvester, the musical talent in Helmholtz and Rayleigh, and the enthusiastic though amateurish pictorial efforts of less important men. That the similarities are to be found also in temperament may be noticed on reading Arnold Bennett's article on 'The Artist and the Public,'[8] where many passages will be seen to be applicable to students of science as well as to writers of fiction.

If we look for distinctions between different individuals, we may find one in their leanings either towards the larger aspects of a question or the microscopic study of detail. The power of focussing simultaneously the wider view and the minute observation is perhaps the most characteristic attribute of those who reach the highest eminence in any profession, but the great majority of men have a notable predilection for the one or other side. Though it is indispensable for a scientific man to study the details of the particular problem he is trying to solve, there are many who will lose interest in it as soon as they believe they can see a clear way through the difficulties without following up their solution to its utmost limits. To them detail, as such, has no interest, and they will open and shut a door a hundred times a day without being even tempted to inquire into the inner working of the lock and latch.

There is only one feature in the operation of the intelligence by means of which a sharp division may possibly be drawn between brain-workers showing special capabilities in different subjects. In some persons thought attaches itself mainly to language, in others to visualised images, and herein lies perhaps the distinction between the literary and scientific gift. Those who, owing to external circumstances, have resided in different countries are sometimes asked in what language they think. Speaking for myself, I have always been obliged to answer that, so far as I can tell, thought is not connected with any language at all. The planning of an experiment or even the critical examination of a theory is to me entirely a matter of mental imagery, and hence the experience, which I think many scientific men must have shared, that the conversion of thought into language, which is necessary when

[8] *English Review*, October 1913.

we wish to communicate its results to others, presents not only the ordinary difficulties of translation but reveals faults in the perfection or sequence of the images. Only when the logic of words finally coincides with the logic of images do we attain that feeling of confidence which makes us certain that our results are correct.

A more detailed examination of the instinctive predilections of a child would, I think, confirm Poincaré's conclusion that a decided preference for one subject is in the main due to an unconscious appeal to his emotions. It should be remembered, however, that the second step of Poincaré's philosophy is as important as the first. The mere emotional impulse would die out quickly, if it were not supplemented by the gratification experienced on discovering that the search for the beautiful leads us to results which satisfy our intellect as well as our emotions. There may still be bifurcations in the second portion of the road. Some may rest content with achieving something that supplies the material needs of humanity, others may be inspired to search for the deeper meaning of our existence.

There remains therefore some justification for the question why we persist in studying science apart from the mere intellectual pleasure it gives us. It was once a popular fallacy to assume that the laws of Nature constituted an explanation of the phenomena to which they applied, and people then attached importance to the belief that we could gauge the mind of the Creator by means of the laws which govern the material world, just as we might trace the purpose of a human legislator in an Act of Parliament. As this archaic interpretation was abandoned, philosophers went, in accordance with what politicians call the swing of the pendulum, to the other extreme. We can explain nothing, they said—in fact, we can know nothing—all we can do is to record facts. This modesty was impressive and it became popular. I know, at any rate, one scientific man who has acquired a great reputation for wisdom by repeating sufficiently often that he knows nothing, and, though his judgment may be true, this frame of mind is not inspiring. As a corrective to the older visionary claims, which centred round the meaning of the word 'explain,' the view that the first task of science is to record facts has no doubt had a good influence. Kirchhoff laid it down definitely that the object of science is to describe Nature, but he did not thereby mean that it should be confined to recording detached observations: this would be the dullest and most unscientific procedure. Description, in the sense in which Kirchhoff uses it, consists in forming a comprehensive statement gathering together what, till then, was only a disconnected jumble of facts. Thus the apparently quite irregular motions of the planets as observed from the earth were first collected in tabular form. This was a necessary

preliminary but was not in itself a scientific investigation. Next came Kepler, who by means of three laws summed up the facts in their main outlines, and the description then took a more refined form, substituting half a page of printing for volumes of observations. Finally, Newton succeeded in predicting the planetary movements on the assumption of a gravitational attraction between all elements of matter. According to Kirchhoff, the chief merit of this discovery would lie in its condensing Kepler's three laws into one hypothesis. This point of view is not necessarily opposed to that of Poincaré, because it is exactly the simplicity of Newton's explanation that appeals most strongly to our æsthetic sense, but there is an important difference in the manner of expression, for however beautiful an idea may be, it loses its effect by being placed before us in an unattractive form. This criticism also applies to Mach, according to whom the object of science is to economize thought, just as it is the object of a machine to economize effort. Logically, this definition is justified, and it may be the best that can be given, if we prefer using a technical expression to confessing an emotional feeling. But why should we do so? Is it not better to recognize that human intelligence is affected by sentiment as much as by reason, and is it not a mistake for scientific men to dissociate themselves from the rest of humanity, by placing their motives on a different, and, at the best, only superficially higher, level? When an adventurous spirit, for instance, desires to organize an expedition to unknown regions of the world, we try to induce our governments to provide the necessary funds by persuading them, and incidentally ourselves, that we do so because important scientific results may be expected from the expedition. This may actually be the case, but we are mainly affected by the same motives as the rest of the community: if the truth be told, we are as curious as others to know what every corner of the earth looks like, and we join them in wishing to encourage an enterprise requiring perseverance and involving danger.

I fully realise that the wish to justify one's own work in the eyes of the world will always lead to fresh attempts to find a formula expressing the objects which we desire to attain. Enough, however, has been said to show that the definition must take account of sentiment, without insisting too much upon it; nor can we hope, in view of the variety of intellectual and emotional pleasures which combine to create the charm of science, to include all points of view, but if I were forced to make a choice I should say that the object of science is to predict the future. The wish to know what lies before us is one of the oldest and most enduring desires of human nature; often, no doubt, it has degenerated and given rise to perverted and ignoble longings, but its

accomplishment, when it can be achieved by legitimate inquiry, is a source of the purest and most satisfying enjoyment that science can give. We feel that enjoyment each time we repeat an old and perhaps hackneyed experiment. The result is known beforehand, but be it only that we expect the colour of a chemical precipitate to be green or yellow, be it only that we expect a spot of light to move to the right or left, there is always a little tremor of excitement at the critical moment and a satisfying feeling of pleasure when our expectation has been realized. That pleasure is, I think, enhanced when the experiment is not of our own making but takes place uncontrolled by human power. In one of Heine's little verses he makes light of the tears of a young lady who is moved by the setting sun. 'Be of good cheer,' the poet consoles her, 'this is only the ordinary succession of events: the sun sets in the evening and rises in the morning.' If Heine had been a man of science, he would have known that the lady's tears found a higher justification in the thought of the immutable and inexorable regularity of the sun's rising and setting than in the fugitive colour impression of his descent below the horizon, and that her emotions ought to be intensified rather than allayed by the thought of his resurrection in the morning. There are in everybody's life a few unforgettable moments which, at quite unexpected times, vividly rise in his mind, and there are probably some in this Hall who have experienced such moments at the beginning of a total eclipse of the sun. They have probably travelled far, and gone through months of preparation, for an event which only lasts a few minutes. The time of first contact is approaching, in a few seconds the moon is about to make its first incision in the solar disc, and now the observer's thoughts come crowding together. What if there were a mistake in our calculations? What if we had chosen a spot a few miles too far north or too far south? What if the laws of gravitation were ever so little at fault?—But now at the predicted time, at the very spot so anxiously watched, the dark moon becomes visible, and the feeling of relief experienced concentrates into one tense instant all the gratitude we owe those who have given precision to the calculations of celestial movements and handed us the key of prediction in a simple law which can be written down in two lines. It is this simplicity of the law of gravitation, and its accuracy, which some day may show limitations, but has hitherto withstood all tests, that gives to Astronomy its pre-eminence over all sciences.

Indeed, if we classify the different sections into which science may be divided, I think it may be said that their aim, in so far as it is not purely utilitarian, is always either historic or prophetic; and to the mathematician, history is only prophecy pursued in the negative direc-

tion. It is no argument against my definition of the objects of science, that a large section of its subdivisions has been, and to some extent still is, mainly occupied with the discovery and classification of facts; because such classification can only be a first step, preparing the way for a correlation into which the element of time must enter, and which therefore ultimately must depend either on history or prophecy.

Latterly men of science, and in particular physicists, have given increased attention to the intrinsic meaning of the concepts by means of which we express the facts of Nature. Everything—who can deny it?—is ultimately reduced to sense impressions, and it has therefore been asserted that science is the study of the mind rather than of the outside world, the very existence of which may be denied. The physicist has thus invaded the realm of philosophy and metaphysics, and even claims that kingdom as his own. Two effects of these efforts, a paralyzing pessimism and an obscure vagueness of expression, if not of thought, seriously threatened a few years ago to retard the healthy progress of the study of Nature. If the outside world were only a dream, if we never could know what really lies behind it, the incentive which has moved those whose names stand out as landmarks in science is destroyed, and it is replaced by what? By a formula which only appeals to a few spirits entirely detached from the world in which they live. Metaphysicians and physicists will continue to look upon science from different points of view, and need not resent mutual criticisms of each other's methods or conclusions. For we must remember that most of the good that is done in this world is done by meddling with other people's affairs, and though the interference is always irritating and frequently futile, it proves after all that our interests converge towards a common centre.

According to Poincaré, the pleasure which the study of science confers consists in its power of uniting the beautiful with the useful; but it would be wrong to adopt this formula as a definition of the object of science, because it applies with equal force to all human studies. I go further, and say that the combination of the search for the beautiful with the achievement of the useful is the common interest of science and humanity. Some of us may tend more in one direction, some in another, but there must always remain a feeling of imperfection and only partial satisfaction unless we can unite the two fundamental desires of human nature.

I have warned you at the beginning of this discourse not to beat the utilitarian drum too loudly, and I have laid stress throughout on the idealistic side, though the most compelling events of the moment seem to drive us in the other direction, and the near future will press the needs of material prosperity strongly upon us. I must guard

myself, therefore, against one criticism which the trend of my remarks may invite. At times, when the struggle for existence keeps masses in permanent bondage, in a society in which a multitude of men and women have to face starvation, and when unfortunate, though purely accidental, surroundings in childhood drive the weak into misery, is it not futile to speak of æsthetic motives? Am I not, while endeavouring to find a common bond between all sections of the community, in reality drawing a ring round a small and privileged leisured class, telling them these enjoyments are for you and for you alone? Should I not have found a surer ground for the claims of science in its daily increasing necessity for the success of our manufactures and commerce?

I have said nothing to indicate that I do not put the highest value on this important function of science, which finds its noblest task in surrendering the richness of its achievements to the use of humanity. But I must ask you to reflect whether the achievement of wealth and power, to the exclusion of higher aims, can lead to more than a superficial prosperity, which passes away because it carries the virus of its own doom within it. Do we not find in the worship of material success the seed of the pernicious ambition which has maddened a nation, and plunged Europe into war? Is this contempt for all idealistic purposes not responsible for the mischievous doctrine that the power to possess confers the right to possess, and that possession is desirable in itself without regard to the use which is made of it? I must therefore insist that if we delight in enlisting the wealth accumulated in the earth, and all the power stored in the orbs of heaven, or in the orbits of atomic structure, it should not be because we place material wealth above intellectual enjoyment, but rather because we experience a double pleasure if the efforts of the mind contribute to the welfare of the nation, which includes spiritual as well as material prosperity. When Joule taught us to utilize the powers at our disposal to the best advantage he did it not—and his whole life is a proof of it—to increase either his own wealth or that of the nation, but because, brought up in commercial life and deeply imbued with the deep insight and genius of science, he found his greatest delight in that very combination of æsthetic satisfaction and useful achievement which Poincaré has so well described. And again, when another of our fellow-citizens, Henry Wilde, showed how electrical power can be accumulated until it became an efficient instrument for the economic transmission of work, he found his inspiration in the intellectual gratification it gave him, rather than in the expectation of material gain. I am drawing no ring round a privileged class, but maintain that the hunger for intellectual enjoyment is universal, and urge that everybody should be given the opportunity and leisure of

appeasing it. The duty to work, the right to live, and the leisure to think are the three prime necessities of our existence, and when one of them fails we only live an incomplete life.

I should have no difficulty in illustrating by examples, drawn from personal experience, the power which the revelations of science can exert over a community steeped in the petty conflicts of ordinary life; but I must bring these remarks to a conclusion, and content myself with the account of one incident.

An American friend, who possessed a powerful telescope, one night received the visit of an ardent politician. It was the time of a Presidential election, Bryan and Taft being the opposing candidates, and feeling ran high. After looking at clusters of stars and other celestial objects, and having received answers to his various questions, the visitor turned to my friend:

'And all these stars I see,' he asked, 'what space in the heaven do they occupy?'

'About the area of the moon.'

'And you tell me that every one of them is a sun like our own?'

'Yes.'

'And that each of them may have a number of planets circulating round them like our sun?'

'Yes.'

'And that there may be life on each of these planets?'

'We cannot tell for certain, but it is quite possible that there may be life on many of them.'

And after pondering for some time, the politician rose and said: 'It does not matter after all whether Taft or Bryan gets in.'

Happy were the times when it could be said with truth that the strife of politics counted as nothing before the silent display of the heavens. Mightier issues are at stake to-day: in the struggle which convulses the world, all intellectual pursuits are vitally affected, and Science gladly gives the power she wields to the service of the State. Sorrowfully she covers her face because that power, acquired through the peaceful efforts of the sons of all nations, was never meant for death and destruction; gladly she helps, because a war wantonly provoked threatens civilization, and only through victory shall we achieve a peace in which once more Science can hold up her head, proud of her strength to preserve the intellectual freedom which is worth more than material prosperity, to defeat the spirit of evil that destroys the sense of brotherhood among nations, and to spread the love of truth.

REPORTS

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The Calculation of Mathematical Tables.—Report of the Committee, consisting of Professor M. J. M. Hill (*Chairman*), Professor J. W. Nicholson (*Secretary*), Dr. J. R. Airey, Mr. T. W. Chaundy, Mr. A. T. Doodson, Professor L. N. G. Filon, Sir George Greenhill, Professors E. W. Hobson, Alfred Lodge, A. E. H. Love, *and* H. M. Macdonald, Mr. H. G. Savidge, *and* Professor A. G. Webster.

Of the grant of 30*l.* given to the Committee, 25*l.* has been expended on the special purposes for which it was allocated—further calculations in connection with the I, Y, and K Bessel functions, the particular calculations selected being in accordance with the frequency of requests for these Tables received by the Secretary from workers in physical science and engineering. The order of calculation is being arranged in accordance with the real urgency of the Tables, and the stage is now coming in sight at which the Committee will be able, as authorised already by the Association at the appropriate time, to publish, under the auspices of the Association, a volume of fairly complete Tables of the more important transcendental functions

The remaining 5*l.* of the grant has been returned to the Association, but the Committee desires to make application for it again, and also for the continuance of the grant of 30*l.* for the ensuing year. The unusual circumstances of the past year temporarily hindered the work, so that the Tables for which this particular part of the grant was estimated are still incomplete but they are well in hand, and some expense has already been incurred in connection with them.

The present Report contains some Tables of which Dr. Airey has been in charge, divided into three sections: (1) The Bessel functions $J_n(x)$ for various orders and arguments which will be apparent from the Tables themselves, their most valuable portions being the entries for which order and argument are approximately the same. These Tables indicate the characteristic tendency towards zero when the order exceeds the argument, as in the formulæ of Nicholson and Debye, which, however, were not employed in the numerical work.

(2) The Neumann functions of types G and Y to a large number of significant figures. These are sufficient to form the basis of a rapid calculation of complete sets of Tables for functions of these types of any order.

(3) Continues the calculation of the functions of type Y from (2) as a basis. The Committee is greatly indebted to Dr. Airey for taking charge of this important work.

The functions ber x, bei x introduced by Lord Kelvin, together with their derivates, are of great importance in connection with alternating currents. In the Report for 1912, the Committee published Tables of these functions and their derivates, calculated by Professor Webster. They are now able, in Table IV. of the present Report, to give the necessary supplement to these Tables—the real and imaginary parts of $K_0(x\,i^{\frac{1}{2}})$, with their derivates—the work having been kindly undertaken and carried through by Mr. H. G. Savidge. For a very complete and general account of the mathematical properties and uses of these functions, reference may be made to a paper by Dr. Alexander Russell ('Phil. Mag.,'

April 1909; and Russell's 'Alternating Currents,' 2nd Edn., vol. 1, chap. VII.).

For the convenience of those who frequently require such Tables, the following summary of some other important Tables of Bessel functions and Zonal Harmonics may be useful:

(1) $J_0(x)$ and $J_1(x)$; range $x = 0$ to 15·5, interval 0·01, to 12 places (Gray and Mathews' Treatise).

(2) $J_n(x)$ from $n = 0$ upwards (integral) to from 16 to 60 according to x: for integral values of x between 1 and 24, to 18 places (*ibid*).

(3) $J_1(x) = 0$; first 50 roots, to 16 places (*ibid.*).

(4) Further Tables of roots of Bessel functions (Airey, 'Proc. Phys. Soc.,' vol. 23 (1911), p. 219)

(5) $J_n(x)$; Tables for calculating phase and amplitude (A. Lodge, 'Brit. Ass. Rep.,' 1907, pp. 94, 95; 1909, p. 33).

(6) $I_1(x)$; range $x = 0$ to 5·1, interval 0·001, to ninth decimal figure, with first difference (Lodge, 'Brit. Ass. Rep.,' 1893, p. 229).

(7) $I_0(x)$; range, &c., as in (6) (*ibid.* 1896, p. 99).

(8) $I_n(x)$; range $x = 0$ to 6, interval 0·2, $n = 0$ to 11 (integral) ('Brit. Ass. Rep.,' 1889, p. 29).

(9) $Y_0(x)$, $Y_1(x)$, $G_0(x)$, $G_1(x)$; range $x = 0$ to 16, interval 0·1, to 7 figures approximately (Airey, 'Brit. Ass. Rep.,' 1913, p. 116).

(10) $K_0(x)$ and $K_1(x)$; range $x = 0$ to 12, interval 0·1, to many figures (Aldis, 'Roy. Soc. Proc.' (1898), vol. lxiv., p. 203).

(11) $K_n(r)$; range $x = 0$ to 5, interval 0·2, to 5 figures (Isherwood, 'Manch. Mem.,' vol. 48 (1904), No. 19.

(12) ber x, bei x, ber′ x, bei′ x: range $x = 0$ to 10, interval 0·1, with first seven differences (Webster, 'Brit. Ass. Rep.,' 1912, p. 57).

(13) Definition, properties, and tables of ber x, ker x, &c., and allied functions (Russell and Savidge, 'Phil. Mag.,' April 1909 and Jan. 1910).

(14) Exact Tables of $P_n(\mu)$ from $n = 1$ to $n = 7$, $\mu = 0$ to $\mu = 1$, interval 0·01 (Glaisher, 'Brit. Ass. Rep.,' 1879, p. 49).

(15) $P_0(\mu)$ to $P_7(\mu)$; four-figure Tables at 1° interval (Perry, 'Phil. Mag.,' Dec. 1891, p. 512).

(16) $P_1(\cos\theta)$ to $P_{20}(\cos\theta)$, $\theta = 0°$ to 90°, interval 5°, 7 figures (Lodge, 'Phil. Trans.,' vol. 203 (1904), p. 100)

The Committee has in course of preparation some sine and cosine Tables proceeding by fractions of radians instead of degrees. A large demand for these Tables has always existed, and, in particular, they will be of very great value for the rapid calculation of large classes of important transcendental functions from their asymptotic series. Those in hand at present are the sine and cosine of angles from 0·01 to 1·60 radians by intervals of 0·01, and from 0·0001 to 0·0100 by intervals of 0·0001. These Tables will be comparatively short, and the calculations are proceeding to 10 significant figures.

Table I.

The Bessel Functions, $J_n(x)$.

These functions have been tabulated by Meissel to eighteen places of decimals for integral values of x from 1 to 24. From the values of $J_0(x)$ and $J_1(x)$, the following supplementary tables have been calculated to six places of decimals from $x = 0·2$ to 6·0 by intervals of 0·2, the actual computation being carried to ten places, and from 6·0 to 16·0 by intervals of 0·5 to ten places from results obtained to twelve places.

Tables of the Bessel Functions $J_n(x)$.

J (x)	x = 0·2	0·4	0·6	0 8	1·0
n = 0	+0·990025	+0·960398	+0·912005	+0·846287	+0·765198
1	+0·099501	+0·196027	+0·286701	+0·368842	+0·440051
2	+0·004983	+0·019735	+0·043665	+0·075818	+0·114903
3	+0·000166	+0·001320	+0·004400	+0·010247	+0·019563
4	+0·000004	+0·000066	+0·000331	+0·001033	+0·002477
5	+0·000000	+0·000003	+0·000020	+0·000083	+0·000250
6	—	—	+0·000001	+0·000006	+0·000021
7	—	—	—	—	+0·000002

$J_n(x)$	x = 1·2	1·4	1 6	1 8	2·0
n = 0	+0·671133	+0·566855	+0·455402	+0·339986	+0·223891
1	+0·498289	+0·541948	+0·569896	+0·581517	+0·576725
2	+0·159349	+0·207356	+0·256968	+0·306144	+0·352834
3	+0·032874	+0·050498	+0·072523	+0·098802	+0·128943
4	+0·005023	+0·009063	+0·014995	+0·023197	+0·033996
5	+0·000610	+0·001290	+0·002452	+0 004294	+0·007040
6	+0·000062	+0·000152	+0·000332	+0·000657	+0·001202
7	+0·000005	+0·000015	+0 000038	+0 000086	+0·000175
8	—	+0·000001	+0·000004	+0 000010	+0·000022
9	—	—	—	—	+0·000002

$J_n(x)$	x = 2 2	2 4	2 6	2·8	3 0
n = 0	+0·110362	+0·002508	−0·096805	−0·185036	−0·260052
1	+0 555963	+0·520185	+0·470818	+0·409709	+0·339059
2	+0 395059	+0·430980	+0 458973	+0·477685	+0·486091
3	+0·162325	+0·198115	+0·235294	+0·272699	+0·309063
4	+0·047647	+0 064307	+0·084013	+0·106669	+0·132034
5	+0 010937	+0·016242	+0 023207	+0 032069	+0·043028
6	+0 002066	+0 003367	+0 005246	+0·007863	+0·011394
7	+0·000332	+0·000593	+0·001005	+0·001631	+0·002547
8	+0 000046	+0 000091	+0 000167	+0·000294	+0·000493
9	+0 000006	+0 000012	+0·000024	+0·000047	+0·000084
10	+0·000001	+0·000002	+0·000003	+0·000007	+0·000013
11	—	—	—	—	+0·000002

$J_n(x)$	x = 3 2	3 4	3 6	3 8	4 0
n = 0	−0·320188	−0·364296	−0·391769	−0·402556	−0·397150
1	+0 261343	+0·179226	+0·095466	+0 012821	−0 066043
2	+0·483528	+0 469723	+0·444805	+0·409304	+0·364128
3	+0·343066	+0·373389	+0·398763	+0·418026	+0·430171
4	+0·159722	+0·189199	+0·219799	+0·250736	+0·281129
5	+0·056238	+0 071785	+0 089680	+0·109840	+0·132087
6	+0·016022	+0·021934	+0 029311	+0 038316	+0·049088
7	+0 003845	+0·005630	+0·008024	+0·011159	+0·015176
8	+0·000798	+0·001248	+0·001894	+0·002797	+0·004029
9	+0·000146	+0·000244	+0·000393	+0·000616	+0·000939
10	+0·000024	+0·000043	+0·000073	+0·000121	+0·000195
11	+0·000004	+0·000007	+0·000012	+0·000021	+0·000037
12	—	+0·000001	+0·000002	+0·000004	+0·000006

Tables of the Bessel Functions $J_n(x)$—continued.

$J_n(x)$	$x=$ 4·2	4·4	4·6	4·8	5·0
$n=0$	−0·376557	−0·342257	−0·296138	−0·240425	−0·177597
1	−0·138647	−0·202776	−0·256553	−0·298500	−0·327579
2	+0·310535	+0·250086	+0·184593	+0·116050	+0·046565
3	+0·434394	+0·430127	+0·417069	+0·395209	+0·364831
4	+0·310029	+0·336450	+0·359409	+0·377960	+0·391232
5	+0·156136	+0·181601	+0·207991	+0·234725	+0·261141
6	+0·061725	+0·076279	+0 092745	+0·111051	+0·131049
7	+0·020220	+0·026433	+0·033953	+0·042901	+0·053376
8	+0·005674	+0·007827	+0·010591	+0·014079	+0·018405
9	+0·001395	+0·002027	+0·002885	+0·004027	+0·005520
10	+0·000306	+0·000467	+0·000699	+0·001023	+0·001468
11	+0·000060	+0·000097	+0·000152	+0·000234	+0·000351
12	+0·000011	+0·000018	+0·000030	+0·000049	+0·000076
13	+0·000002	+0·000003	+0·000005	+0·000009	+0·000015

$J_n(x)$	$x=$ 5·2	5·4	5·6	5·8	6·0
$n=0$	−0·110290	−0·041210	+0·026971	+0 091703	+0·150645
1	−0 343223	0 345345	−0·334333	−0 311028	−0 276684
2	−0 021718	−0 086695	- 0·146375	- 0 198954	−0·242873
3	+0·326517	+0 281126	+0·229779	+0·173818	+0·114768
4	+0·398468	+0·399058	+0 392567	+0·378765	+0·357642
5	+0·286512	+0·310074	+0·331031	+0·348617	+0·362087
6	+0·152515	+0·175147	+0·198559	+0·222298	+0·245837
7	+0·065447	+0·079145	+0·091452	+0·111310	+0·129587
8	+0·023689	+0·030044	+0·037571	+0·046382	+0·056532
9	+0·007441	+0·009873	+0·012893	+0·016641	+0·021165
10	+0·002069	+0·002868	+0 003870	+0 005261	+0·006964
11	+0·000517	+0·000747	+0·000930	+0·001500	+0·002048
12	+0·000117	+0·000177	+0·000262	+0·000380	+0·000545
13	+0·000024	+0·000037	+0·000057	+0·000088	+0·000133

$J_n(x)$	$x=$ 6·5	7·0	7·5	8·0
$n=0$	+0·2600946056	+0·3000792705	+0·2663396579	+0·1716508071
1	−0·1538413014	−0·0046828235	+0·1352484276	+0·2346363469
2	−0·3074302368	−0·3014172201	−0·2302734105	−0·1129917204
3	−0·0353465366	−0·1675555880	−0·2580609132	−0·2911322071
4	+0·2748026645	+0·1577981447	+0·0238246800	−0·1053574349
5	+0·3735652006	+0·3478963248	+0·2834739052	+0·1857747722
6	+0·2999130288	+0·3391966050	+0·3541405269	+0·3375759001
7	+0·1801203909	+0·2335835695	+0·2831509379	+0·3205890780
8	+0·0880385825	+0·1279705340	+0·1744078905	+0·2234549864
9	+0·0365899659	+0·0589205083	+0·0889192285	+0·1263208947
10	+0·0132874770	+0·0235393444	+0·0389982579	+0·0607670268
11	+0·0042945787	+0·0083347614	+0·0150761259	+0·0255966722
12	+0·0012480202	+0·0026556200	+0·0052250447	+0·0096238218
13	−0·0003135057	+0·0007702216	+0·0016440171	+0·0032747932

Tables of the Bessel Functions $J_n(x)$—continued.

$J_n(x)$	$x=$ 8·5	9·0	9·5	10·0
$n=0$	+0·0419392518	−0·0903336112	−0·1939287477	−0·2459357645
1	+0·2731219637	+0·2453117866	+0·1612644308	+0·0434727462
2	+0·0223247396	+0·1448473415	+0·2278791542	+0·2546303137
3	−0·2626162039	−0·1809351903	−0·0653153132	+0·0583793793
4	−0·2076773541	−0·2654708018	−0·2691309309	−0·2196026861
5	+0·0671551647	−0·0550388557	−0·1613212602	−0·2340615282
6	+0·2866834302	+0·2043165177	+0·0993190781	−0·0144588421
7	+0·3375743838	+0·3274608792	+0·2867769378	+0·2167109177
8	+0·2693214373	+0·3050670723	+0·3232995671	+0·3178541268
9	+0·1693836158	+0·2148805825	+0·2577275962	+0·2918556853
10	+0·0893732784	+0·1246940928	+0·1650264047	+0·2074861066
11	+0·0409064511	+0·0622174015	+0·0896964138	+0·1231165280
12	+0·0165022421	+0·0273928887	+0·0426916061	+0·0633702550
13	+0·0056881149	+0·0108303016	+0·0181560647	+0·0289720839

$J_n(x)$	$x=$ 10·5	11·0	11·5	12·0
$n=0$	−0·2366481945	−0·1711903004	−0·0676539481	+0·0476893108
1	−0·0788500142	−0·1767852990	−0·2283786207	−0·2234471045
2	+0·2216291441	+0·1390475188	+0·0279359271	−0·0849304949
3	+0·1632801644	+0·2273480331	+0·2380954649	+0·1951369395
4	−0·1283261931	−0·0150395007	+0·0962877937	+0·1824989646
5	−0·2610525019	−0·2382858518	−0·1711126519	−0·0734709631
6	−0·1202952374	−0·2015840009	−0·2450838970	−0·2437247672
7	+0·1235722307	+0·0183760326	−0·0846270668	−0·1702538041
8	+0·2850582116	+0·2249716788	+0·1420596418	+0·0450953291
9	+0·3108021870	+0·3088555001	+0·2822752641	+0·2303809096
10	+0·2477455375	+0·2804282305	+0·2997625107	+0·3004760353
11	+0·1610940750	+0·2010140099	+0·2390508414	+0·2704124826
12	+0·0897849053	+0·1215997893	+0·1575521425	+0·1952801827
13	+0·0441285657	+0·0642946213	+0·0897536298	+0·1201478829

$J_n(x)$	$x=$ 12·5	13·0	13·5	14·0
$n=0$	+0·1468840547	+0·2069261024	+0·2149891659	+0·1710734761
1	−0·1654838046	−0·0703180521	+0·0380492921	+0·1333751547
2	−0·1733614634	−0·2177442642	−0·2093522337	−0·1520198826
3	+0·1100081363	+0·0033198170	−0·1000795836	−0·1768094069
4	+0·2261653689	+0·2192764875	+0·1648724188	+0·0762444225
5	+0·0347376998	+0·1316195599	+0·1977817577	+0·2203776483
6	−0·1983752091	−0·1180306721	−0·0183674131	+0·0811681834
7	−0·2251779005	−0·2405709496	−0·2141083471	−0·1508049196
8	−0·0538240395	−0·1410457351	−0·2036710209	−0·2319731031
9	+0·1562831300	+0·0669761987	−0·0272791962	−0·1143071982
10	+0·2788717466	+0·2337820102	+0·1672987593	+0·0850067054
11	+0·2899116646	+0·2926884324	+0·2751292100	+0·2357453488
12	+0·2313727831	+0·2615368754	+0·2810599533	+0·2854502712
13	+0·1543240789	+0·1901488760	+0·2245329292	+0·2535979733

Tables of the Bessel Functions $J_n(x)$—continued.

$J_n(x)$	$x = 14{\cdot}5$	15·0	15·5	16·0
$n = 0$	+0·0875448680	−0·0142244728	−0·1092306509	−0·1748990740
1	+0·1934294636	+0·2051040386	+0·1672131804	+0·0903971757
2	−0·0608649420	+0·0415716780	+0·1308065451	+0·1861987209
3	−0·2102197923	−0·1940182578	−0·1334566526	−0·0438474954
4	−0·0261220608	−0·1191789811	−0·1824671848	−0·2026415317
5	+0·1958076209	+0·1304561346	+0·0392800410	−0·0574732704
6	+0·1611617993	+0·2061497375	+0·2078091468	+0·1667207377
7	−0·0624323387	+0·0344636554	+0·1216044597	+0·1825138237
8	−0·2214412987	−0·1739836591	−0·0979728606	−0·0070211420
9	−0·1819166806	−0·2200462251	−0·2227377352	−0·1895349657
10	−0·0043863048	−0·0900718110	−0·1606903157	−0·2062056944
11	+0·1758666050	+0·0999504771	+0·0153953923	−0·0682221524
12	+0·2712183952	+0·2366658441	+0·1825418403	+0·1124002349
13	+0·2730466008	+0·2787148734	+0·2672500378	+0·2368225048

Table II.

The Neumann Functions $G_0(x)$, $G_1(x)$, $Y_0(x)$, and $Y_1(x)$.

The Neumann Functions or Logarithmic Bessel Functions, $G_0(x)$ and $G_1(x)$, were calculated to twelve or more places of decimals for values of the argument 6·5 to 15·5 from their asymptotic expansions.

$$G_0(x) = -\sqrt{\frac{\pi}{2x}}\left[P_0(x)\sin\left(x-\frac{\pi}{4}\right)+Q_0(x)\cos\left(x-\frac{\pi}{4}\right)\right]$$

and
$$G_1(x) = +\sqrt{\frac{\pi}{2x}}\left[P_1(x)\cos\left(x-\frac{\pi}{4}\right)-Q_1(x)\sin\left(x-\frac{\pi}{4}\right)\right]$$

If the calculation be restricted to the convergent part of $P_0(x)$, $Q_0(x)$, &c., the value of $G_0(6\,5)$ can be found to about seven places of decimals, but it is possible to transform the divergent part of any one of these series and express it as a fraction of the least term of the convergent part of the series.[1] The fraction or 'converging factor' is a function of x in descending powers of the variable, the absolute term being $\frac{1}{2}$. By this means, $G_0(6{\cdot}5)$, &c., can be calculated to about twelve or more places of decimals. The functions $Y_0(x)$ and $Y_1(x)$ were then found from the relations $Y_0(x) = (\log 2 - \gamma)\,J_0(x) - G_0(x)$, &c.

Tables of the Neumann Functions $G_0(x)$ and $G_1(x)$.

x	G_0	G_1	x	G_0	G_1
6·5	+0·2721285804	+0·4305415662	11·5	+0·3537937737	−0·0910159402
7·0	+0·0407617621	+0·4754285799	12·0	+0·3538019433	+0·0896912423
7·5	−0·1842752790	+0·4070381044	12·5	+0·2689428043	+0·2416485683
8·0	−0·3511067345	+0·2482807927	13·0	+0·1228486263	+0·3299951047
8·5	−0·4244371900	+0·0411056655	13·5	−0·0472448553	+0·3361864328
9·0	−0·3925996476	−0·1638569516	14·0	−0·1997936195	+0·2617651055
9·5	−0·2689370228	−0·3191542396	14·5	−0·2989255117	+0·1273006187
10·0	−0·0874480651	−0·3911525137	15·0	−0·3227425615	−0·0331023775
10·5	+0·1060764611	−0·3671017435	15·5	−0·2680483997	−0·1803056510
11·0	+0·2652247562	−0·2571480569			

[1] *Annales de l'Ecole Normale Supérieure*, 1886; *Archiv der Math. und Physik*, 1914.

Tables of the Neumann Functions $Y_0(x)$ and $Y_1(x)$.

x	Y_0	Y_1	x	Y_0	Y_1
0·1	−2·2943345812	−10·1399073252	4·1	−0·1331722948	+0·5921462686
0·2	−1·5834211860	−5·2095168052	4·2	−0·1909188721	+0·5619996237
0·3	−1·1547246989	−3·5848063074	4·3	−0·2454213266	+0·5273274052
0·4	−0·8406007621	−2·7746616109	4·4	−0·2962466600	+0·4885254644
0·5	−0·5894501822	−2·2832968788	4·5	−0·3430028852	+0·4460183107
0·6	−0·3788760747	−1·9465804215	4·6	−0·3853417720	+0·4002554688
0·7	−0·1973368285	−1·6948398823	4·7	−0·4229611239	+0·3517074948
0·8	−0·0382373343	−1·4937048735	4·8	−0·4556066658	+0·3008618391
0·9	+0·1024583688	−1·3244416941	4 9	−0·4830735596	+0·2482186095
1·0	+0·2273442324	−1·1761105040	5·0	−0·5052074159	+0·1942861461
1·1	+0·3381522214	−1·0420112190	5·1	−0 5219048840	+0·1395766012
1·2	+0·4360781497	−0·9179113341	5·2	−0·5331138832	+0·0846015427
1·3	+0·5219761866	−0·8010938444	5·3	−0·5388332402	+0·0298674819
1·4	+0·5964807906	−0·6898134973	5·4	−0·5391120024	−0·0241284674
1·5	+0·6600863177	−0·5829704614	5·5	−0·5340482919	−0·0769027972
1·6	+0·7132004847	−0·4799053721	5·6	−0·5237877109	−0·1279897534
1·7	+0·7561813379	−0·3802657536	5·7	−0·5085214159	−0·1769452265
1·8	+0·7893631174	−0·2839158153	5·8	−0·4884837051	−0·2233504152
1·9	+0·8130746390	−0·1908735689	5·9	−0·4639493697	−0·2668153484
2·0	+0·8276522282	−0·1012655792	6·0	−0·4352306154	−0·3069819855
2·1	+0·8334488985	−0·0152936185	6·5	−0·2419754186	−0·4483766215
2·2	+0·8308405095	+0·0667906385	7·0	−0·0059731175	−0·4759714667
2·3	+0·8202297417	+0·1447052444	7·5	+0·2151524392	−0·3913585492
2·4	+0·8020483338	+0·2181535173	8·0	+0·3710064727	−0·2210790454
2·5	+0·7767578849	+0·2868365398	8·5	+0·4292992711	−0·0094422223
2·6	+0·7448495748	+0·3504634353	9 0	+0·3821271351	+0·1922963188
2·7	+0·7068429107	+0·4087597225	9·5	+0·2464545691	+0·3378498695
2·8	+0·6632837280	+0 4614743384	10·0	+0·0589363592	+0·3961923750
2·9	+0·6147415401	+0·5083854239	10·5	−0·1335114449	+0·3579605418
3·0	+0·5618063930	+0·5493050123	11·0	−0·2850711072	+0·2366530692
3·1	+0·5050853059	+0·5840829410	11·5	−0·3616369985	+0·0645396606
3·2	+0·4451982191	+0 6126099179	12·0	−0·3482732493	−0·1155958038
3·3	+0·3827739309	+0·6348198099	12·5	−0·2519143132	−0·2608333566
3·4	+0·3184455929	+0·6506912753	13·0	−0·0988593697	−0·3381471830
3·5	+0·2528462007	+0·6602488398	13·5	+0·0721688752	−0·3317753207
3·6	+0·1866039774	+0·6635633127	14·0	+0·2196264269	−0·2463027216
3·7	+0·1203377889	+0·6607516305	14·5	+0·3090147209	−0·1048760479
3·8	+0·0546524956	+0·6519761906	15·0	+0·3210934968	+0·0568803996
3·9	−0·0098655002	+0·6374437509	15·5	+0·2553851248	+0·1996909285
4·0	−0·0726526231	+0·6174037456			

Table III.

The Neumann Functions $Y_n(x)$.

From the foregoing values of $Y_0(x)$ and $Y_1(x)$ functions of higher order were computed by means of the recurrence formula

$$Y_{n+1}(x) = \frac{2n}{x} Y_n(x) - Y_{n-1}(x).$$

The calculations were carried as far as the tenth place and verified by the relation

$$J_{n+1}(x)\, Y_n(x) - J_n(x)\, Y_{n+1}(x) = \frac{1}{x}.$$

Tables of the Neumann Functions $Y_n(x)$.

$Y_n(x)$	$x=$ 0·2	0·4	0·6	0·8	1·0
$n=0$	−1·583421	−0·840601	0·378876	−0·038237	+0·227344
1	−5·209517	−2·774662	−1·946580	−1·493705	−1·176111
2	—	—	−6·109725	−3·696025	−2·579565
3	—	—	—	—	−9·142150

$Y_n(x)$	$x=$ 1·2	1·4	1·6	1·8	2·0
$n=0$	+0·436078	+0·596481	+0·713200	+0·789363	+0·827652
1	−0·917911	−0·689813	−0·479905	−0·283916	−0·101266
2	−1·965930	−1·581929	−1·313082	−1·104825	−0·928918
3	−5·635190	−3·829983	−2·802800	−2·171251	−1·756570
4	—	—	−9·197418	−6·132679	−4·340792

$Y_n(x)$	$x=$ 2·2	2·4	2·6	2·8	3·0
$n=0$	+0·830841	+0·802048	+0·744850	+0·663284	+0·561806
1	+0·066791	+0·218154	+0·350463	+0·461474	+0·549305
2	−0·770122	−0·620254	−0·475262	−0·333659	−0·195603
3	−1·467012	−1·251910	−1·081636	−0·938130	−0·810109
4	−3·230820	−2·509521	−2·020821	−1·676620	−1·424615
5	−10·281425	−7·113159	−5·136275	−3·852213	−2·988865
6	—	—	—	—	−8·538267

$Y_n(x)$	$x=$ 3·2	3·4	3·6	3·8	4·0
$n=0$	+0·445198	+0·318446	+0·186604	+0·054652	−0·072653
1	+0·612610	+0·650691	+0·663563	+0·651976	+0·617404
2	−0·062317	+0·064314	+0·182042	+0·289019	+0·381354
3	−0·690506	−0·575028	−0·461294	−0·347745	−0·236049
4	−1·232382	−1·079069	−0·950866	−0·838091	−0·735428
5	−2·390449	−1·963958	−1·651741	−1·416657	−1·234807
6	−6·237771	−4·697278	−3·637304	−2·889953	−2·351590
7	—	—	−10·472604	−7·709510	−5·819964

$Y_n(x)$	$x=$ 4·2	4·4	4·6	4·8	5·0
$n=0$	−0·190919	−0·296247	−0·385342	−0·455607	−0·505207
1	+0·562000	+0·488525	+0·400255	+0·300862	+0·194286
2	+0·458538	+0·518304	+0·559366	+0·580966	+0·582922
3	−0·125297	−0·017340	+0·086150	+0·183276	+0·272051
4	−0·637533	−0·541950	−0·446997	−0·351870	−0·256460
5	−1·089052	−0·968023	−0·863535	−0·769727	−0·682388
6	−1·955449	−1·658102	−1·430254	−1·251727	−1·108315
7	−4·497915	−3·554073	−2·867562	−2·359592	−1·977569
8	—	−9·650312	−7·297109	−5·630415	−4·428878

Tables of the Neumann Functions $Y_n(x)$—continued.

$Y_n(x)$	$x =$ 5·2	5·4	5·6	5·8	6·0
$n = 0$	−0·533114	−0·539112	−0·523788	−0·488484	−0·435231
1	+0·084602	−0·024128	−0·127990	−0·223350	−0·306982
2	+0·565653	+0·530176	+0·478077	+0·411466	+0·332903
3	+0·350516	+0·416851	+0·469473	+0·507120	+0·528918
4	−0·161211	−0 067008	+0·024930	+0·113141	+0·196014
5	−0·598533	−0·516122	−0·433859	−0·351064	−0·267565
6	−0·989815	−0·888773	−0·799678	−0·718423	−0·641956
7	−1·685654	−1·458930	−1·279737	−1·135329	−1·016347
8	−3·548485	−2·893638	−2·399665	−2·022027	−1·729521
9	−9·232761	−7·114812	−5·576448	−4·442676	−3·595708
10	—	—	—	—	−9·057603

$Y_n(x)$	$x =$ 6·0	6·5	7 0	7·5	8·0
$n = 0$	−0·435231	−0·241976	−0·005973	+0·215153	+0·371006
1	−0·306982	−0·448377	−0·475971	−0 391359	−0·221079
2	+0·332903	+0·104013	−0·130019	−0·319515	−0·426276
3	+0·528918	+0·512385	+0·401675	+0·220951	+0·007941
4	+0·196014	+0·368957	+0·474312	+0·496275	+0·432232
5	−0·267565	−0 058284	+0·140395	+0·308410	+0·424291
6	−0·641956	−0·458624	−0·273747	−0·085062	+0·098132
7	−1·016347	−0·788408	−0·609676	−0·444510	−0·277093
8	−1·729521	−1·239484	−0·945604	−0·744689	−0·583045
9	−3·595708	−2·262630	−1·551706	−1·144160	−0·888997
10	−9·057603	−5·026261	−3·044496	−2·001295	−1·417198
11	—	—	−7·146856	−4·192626	−2·653998
12	—	—	—	−10·297074	−5·881296
13	—	—	—	—	—

$Y_n(x)$	$x =$ 8 5	9·0	9 5	10·0	10·5
$n = 0$	+0·429299	+0·382127	+0·246455	+0·058936	−0·133511
1	−0·009442	+0·192296	+0·337850	+0·396192	+0·357961
2	−0·431521	−0·339395	−0·175328	+0·020302	+0·201694
3	−0·193626	−0·343138	−0·411672	−0·388072	−0·281125
4	+0·294843	+0·110636	−0·084675	−0·253145	−0·362337
5	+0·471126	+0·441481	+0·340367	+0·185556	+0·005058
6	+0·259423	+0·379899	+0·442956	+0·438701	+0·367154
7	−0·104882	+0·065051	+0·219157	+0·340885	+0·414547
8	−0·432170	−0·278709	−0·119988	+0·038539	+0·185575
9	−0·708614	−0·560533	−0·421242	−0·279223	−0·131766
10	−1·068425	−0·842358	−0·678155	−0·541141	−0·411460
11	−1·805327	−1·311373	−1·006452	−0·803058	−0·651967
12	−3·604185	−2·363220	−1·652577	−1·225587	−0·954566
13	−8·371196	−4·990547	−3·168479	−2·138350	−1·529898

Tables of the Neumann Functions $Y_n(x)$—continued.

$Y_n(x)$	$x=$ 11·0	11·5	12·0	12·5	13·0
$n=0$	−0·285071	−0·361637	−0·348273	−0·251914	−0·098859
1	+0·236653	+0·064540	−0·115596	−0·260834	−0·338147
2	+0·328099	+0·372861	+0·329007	+0·210181	+0·046837
3	−0·117344	+0·065151	+0 225265	+0·328091	+0·352558
4	−0·392105	−0·338869	−0·216375	−0·052697	+0·115883
5	−0·167823	−0·300886	−0·369515	−0·361817	−0·281246
6	+0·239539	+0·077229	−0 091554	−0·236757	−0·332226
7	+0·429138	+0·381473	+0·277960	+0·134531	−0·025424
8	+0·306637	+0·387173	+0·415842	+0·387431	+0·304846
9	+0·016879	+0·157203	+0·276495	+0·361381	+0·400619
10	−0·279016	−0·141117	−0·001099	+0·132958	+0·249857
11	−0·524181	−0·402623	−0·278327	−0·148649	−0·016223
12	−0·769347	−0·629119	−0·509167	−0·394580	−0·277312
13	−1·154393	−0·910321	−0·740007	−0·608945	−0·495738

$Y_n(x)$	$x=$ 13 5	14 0	14 5	15·0	15·5
$n=0$	+0 072169	+0·219626	+0·309075	+0·321093	+0·255385
1	−0·331775	−0·246303	−0·104876	+0·056880	+0·199691
2	−0 121321	−0·254813	−0·323540	−0·313509	−0·229619
3	+0·295828	+0·173499	+0·015624	−0·140483	−0·258947
4	+0·252800	+0·329169	+0·330005	+0·257316	+0·129378
5	−0·146021	+0 014598	+0·166448	+0·277718	+0·325723
6	- 0·360964	−0 318742	−0·215213	−0 072171	+0·080766
7	−0·174836	−0·287805	−0·344556	−0·335455	−0·263194
8	+0 179653	+0·030937	−0·117461	−0·240920	−0·318490
9	+0·387757	+0 323162	+0·214943	+0 078473	−0·065570
10	+0·337357	+0 384557	+0 384288	+0 335088	+0·242345
11	+0·112031	+0·226205	+0·315109	+0·368311	+0·378272
12	−0·154788	−0·029092	+0·093808	+0·205101	+0·294558
13	−0·387210	−0·276077	−0·159840	−0·040149	+0·077818

Table IV. (*Mr. Savidge's Table.*)

Tables of the Functions $\ker x$, $\mathrm{kei}\, x$, $\frac{d}{dx}(\ker x)$, $\frac{d}{dx}\cdot(\mathrm{kei}\, x)$,

$$\ker x + \iota\, \mathrm{kei}\, x = \mathrm{K}_0(x\sqrt{\iota}).$$

x	$\ker x$	$\mathrm{kei}\, x$	$\ker' x$	$\mathrm{kei}' x$
0	+ ∞	−0·7853982	− ∞	0
·1	+2·4204740	−0·7768506	−9·9609593	+0·1459748
·2	+1·7331427	−0·7581249	−4·9229485	+0·2229268
·3	+1·3372186	−0·7331019	−3·2198652	+0·2742921
·4	+1·0626239	−0·7038002	−2·3520699	+0·3095140
·5	+0·8559059	−0·6715817	−1·8197998	+0·3332038
·6	+0·6931207	−0·6374495	−1·4565386	+0·3481644
·7	+0·5613783	−0·6021755	−1·1909433	+0·3563095
·8	+0·4528821	−0·5663676	−0·9873351	+0·3590425
·9	+0·3625148	−0·5305111	−0·8258687	+0·3574432
1·0	+0·2867062	−0·4949946	−0·6946039	+0·3523699
1·1	+0·2228445	−0·4601295	−0·5859053	+0·3445210
1·2	+0·1689456	−0·4261636	−0·4946432	+0·3344739

Table IV. (*Mr. Savidge's Table*)—continued.

x	ker x	kei x	ker′ x	kei′ x
1·3	+0·1234554	−0·3932918	−0·4172274	+0·3227118
1·4	+0·0851260	−0·3616648	−0·3510551	+0·3096416
1·5	+0·0529349	−0·3313956	−0·2941816	+0·2956081
1·6	+0·0260299	−0·3025655	−0·2451147	+0·2809038
1·7	+0·0036911	−0·2752288	−0·2026818	+0·2657772
1·8	−0·0146961	−0·2494171	−0·1659424	+0·2504385
1·9	−0·0296614	−0·2251422	−0·1341282	+0·2350657
2·0	−0·0416645	−0·2024001	−0·1066010	+0·2198079
2·1	−0·0511065	−0·1811726	−0·0828234	+0·2047897
2·2	−0·0583388	−0·1614307	−0·0623373	+0·1901137
2·3	−0·0636705	−0·1431357	−0·0447479	+0·1758638
2·4	−0·0673735	−0·1262415	−0·0297123	+0·1621069
2·5	−0·0696880	−0·1106961	−0·0169298	+0·1488954
2·6	−0·0708257	−0·0964429	−0·0061358	+0·1362689
2·7	−0·0709736	−0·0834219	+0·0029043	+0·1242558
2·8	−0·0702963	−0·0715707	+0·0103990	+0·1128748
2·9	−0·0689390	−0·0608255	+0·0165342	+0·1021362
3·0	−0·0670292	−0·0511219	+0·0214762	+0·0920431
3·1	−0·0646786	−0·0423955	+0·0253738	+0·0825922
3·2	−0·0619848	−0·0345823	+0·0283603	+0·0737752
3·3	−0·0590329	−0·0276197	+0·0305554	+0·0655794
3·4	−0·0558966	−0·0214463	+0·0320662	+0·0579881
3·5	−0·0526393	−0·0160026	+0·0329886	+0·0509821
3·6	−0·0493156	−0·0112311	+0·0334087	+0·0445394
3·7	−0·0459717	−0·0070767	+0·0334030	+0·0386364
3·8	−0·0426469	−0·0034867	+0·0330400	+0·0332480
3·9	−0·03937361	−0·00041081	+0·03238046	+0·02834832
4·0	−0·03617885	+0·00219840	+0·03147849	+0·02391062
4·1	−0·03308440	+0·00438582	+0·03038179	+0·01990804
4·2	−0·03010758	+0·00619361	+0·02913242	+0·01631367
4·3	−0·02726177	+0·00766127	+0·02776730	+0·01310084
4·4	−0·02455689	+0·00882562	+0·02631868	+0·01024331
4·5	−0·02199988	+0·00972092	+0·02481454	+0·00771543
4·6	−0·01959503	+0·01037886	+0·02327908	+0·00549226
4·7	−0·01734441	+0·01082872	+0·02173300	+0·00354976
4·8	−0·01524819	+0·01109740	+0·02019391	+0·00186478
4·9	−0·01330490	+0·01120953	+0·01867661	+0·00041522
5·0	−0·01151173	+0·01118759	+0·01719340	−0·00081998
5·1	−0·00986474	+0·01105201	+0·01575436	−0·00186079
5·2	−0·00835911	+0·01082128	+0·01436757	−0·00272605
5·3	−0·00698928	+0·01051206	+0·01303935	−0·00343349
5·4	−0·00574913	+0·01013929	+0·01177446	−0·00399969
5·5	−0·00463216	+0·00971631	+0·01057633	−0·00444016
5·6	−0·00363156	+0·00925496	+0·00944717	−0·00476928
5·7	−0·00274038	+0·00876572	+0·00838818	−0·00500041
5·8	−0·00195158	+0·00825774	+0·00739967	−0·00514584
5·9	−0·00125812	+0·00773902	+0·00648121	−0·00521689
6·0	−0·00065304	+0·00721649	+0·00563171	−0·00522392
6·1	−0·00012953	+0·00669606	+0·00484957	−0·00517637
6·2	+0·00031905	+0·00618275	+0·00413275	−0·00508283
6·3	+0·00069912	+0·00568077	+0·00347886	−0·00495105
6·4	+0·00101683	+0·00519358	+0·00288523	−0·00478803
6·5	+0·001278080	+0·004723992	+0·002348995	−0·004600032
6·6	+0·001488446	+0·004274219	+0·001867130	−0·004392632
6·7	+0·001653215	+0·003845947	+0·001436521	−0·004170782
6·8	+0·001777354	+0·003440398	+0·001053999	−0·003938849
6·9	+0·001865512	+0·003058385	+0·000716382	−0·003700651
7·0	+0·001922022	+0·002700365	+0·000420510	−0·003459509
7·1	+0·001950901	+0·002366486	+0·000163267	−0·003218285

Table IV. (*Mr. Savidge's Table*)—continued.

x	ker x	kei x	ker' x	kei' x
7·2	+0·001955861	+0·002056629	−0·000058386	−0·002979421
7·3	+0·001940312	+0·001770454	−0·000247403	−0·002744978
7·4	+0·001907373	+0·001507429	−0·000406628	−0·002516671
7·5	+0·001859888	+0·001266868	−0·000538787	−0·002295904
7·6	+0·001800431	+0·001047959	−0·000646478	−0·002083800
7·7	+0·001731326	+0·000849790	−0·000732165	−0·001881234
7·8	+0·001654654	+0·000671373	−0·000798170	−0·001688855
7·9	+0·001572275	+0·000511664	−0·000846677	−0·001507120
8·0	+0·001485834	+0·000369584	−0·000879724	−0·001336313
8·1	+0·001396782	+0·000244032	−0·000899210	−0·001176567
8·2	+0·001306386	+0·000133902	−0·000906891	−0·001027888
8·3	+0·001215743	+0·000038090	−0·000904388	−0·000890168
8·4	+0·001125797	−0·000044491	−0·000893190	−0·000763209
8·5	+0·001037349	−0·000114902	−0·000874656	−0·000646733
8·6	+0·000951070	−0·000174175	−0·000850022	−0·000540398
8·7	+0·000867511	−0·000223306	−0·000820407	−0·000443813
8·8	+0·000787120	−0·000263248	−0·000786819	−0·000356543
8·9	+0·000710249	−0·000294910	−0·000750159	−0·000278127
9·0	+0·000637164	−0·000319153	−0·000711231	−0·000208079
9·1	+0·000568055	−0·000336788	−0·000670745	−0·000145903
9·2	+0·000503046	−0·000348579	−0·000629326	−0·000091093
9·3	+0·000442203	−0·000355236	−0·000587517	−0·000043145
9·4	+0·000385540	−0·000357420	−0·000545789	−0·000001559
9·5	+0·000333029	−0·000355743	−0·000504544	+0·000034158
9·6	+0·000284604	−0·000350768	−0·000464122	+0·000064485
9·7	+0·000240168	−0·000343010	−0·000424806	+0·000089887
9·8	+0·000199598	−0·000332940	−0·000386830	+0·000110811
9·9	+0·000162751	−0·000320983	−0·000350379	+0·000127684
10	+0·000129466	−0·000307524	−0·000315597	+0·000140914

Investigation of the Upper Atmosphere.—Fourteenth Report of the Committee, consisting of Sir Napier Shaw (*Chairman*), Mr. E. Gold (*Secretary*), Messrs. C. J. P. Cave *and* W. H. Dines, Dr. R. T. Glazebrook, Sir J. Larmor, Professor J. E. Petavel, Dr. A. Schuster, *and* Dr. W. Watson. (*Drawn up by the Secretary.*)

The Committee has not met during the past year and no expenditure has been incurred. There is no immediate prospect of further research, but it is desirable that the Committee should not lapse; a report on the investigations over the ocean, made in July 1914, is not yet completed; and further investigations ought to be made when arrangements can be made for them. It is therefore recommended that the Committee be reappointed with a grant of 25*l.* Last year's grant of 25*l.* has not been claimed.

Radiotelegraphic Investigations.—Report of the Committee, consisting of Sir OLIVER LODGE (*Chairman*), Dr. W. H. ECCLES (*Secretary*), Mr. SIDNEY G. BROWN, Dr. C. CHREE, Professor A. S. EDDINGTON, Dr. ERSKINE-MURRAY, Professors J. A. FLEMING, G. W. O. HOWE, H. M. MACDONALD, *and* J. W. NICHOLSON, Sir HENRY NORMAN, Captain H. R. SANKEY, Professor A. SCHUSTER, Sir NAPIER SHAW, Professor S. P. THOMPSON, *and* Professor H. H. TURNER.

Effect of the War on the Work of the Committee.

THE war has had a very direct effect on radiotelegraphic investigations. About the beginning of August 1914 private wireless telegraph stations throughout the Empire nearly all stopped collecting statistics, while naval and other Government stations stopped all merely scientific observing. The radiotelegraphic stations in Russia, Germany, and neighbouring countries doubtless discontinued the filling up of our forms as soon as mobilisation began. A few stations in India, Australia, Canada, the West Indies, and the United States are, however, still at work. In the last-named country about 30 stations are making observations.

The Committee's programme for the collection of statistics three days a week in all parts of the English-speaking world, and in a few other countries, was planned to embrace one complete round of the seasons. The fact that the programme has been interrupted after only three months of work diminishes greatly the scientific value of such statistics as have been collected. It also implies considerable financial loss. A large batch of Forms was distributed to our Navy in July; in clearing for action these Forms would probably be wasted. The German edition was distributed in June. The Russian edition also was probably distributed before the outbreak of war.

The extensive scheme of special observations projected for the occasion of the solar eclipse failed almost completely in the countries in which the eclipse was visible. A small amount of work was done in Norway and Sweden All the necessary Forms had been printed, and some had been circulated, before the war started. The financial loss to the Committee in this respect exceeds a hundred pounds.

The day-by-day statistics collected in the period April to July have been partially analysed. The conclusions drawn from these observations are described below. Apart from any scientific value they possess they yield information which will guide the Committee, when the time comes, to further attacks on the problems concerned. A similar thought may be set down as consolation for the eclipse failure.

Analysis of Records of Strays.

Diurnal Variations.

The principal and most universal fact is that the strays heard in the dark hours are much more numerous and louder than those heard during

daylight. If curves be drawn showing the amount of disturbance to telegraphic work from hour to hour, two types of curve stand out: one in which the changes from day to night and night to day conditions are somewhat abrupt, and another in which the changes are much more gradual. The former curves might be called 'trough-shaped,' the latter 'U-shaped.' The former type is met with at sea and on islands at a considerable distance from the mainland, the other on the mainland, especially in the tropics. The lowest point of the U or of the trough usually falls a little after midday, and the highest point of the convex part of the curve occurs a little after midnight, in nearly all stations north of the Equator. The only exception to this rule is found in some records from Lagos, Nigeria, where the curve showing the intensity of disturbance is lowest about seven in the morning and rises during the daylight hours. Unless local weather conditions are producing great disturbance, the change from night to day conditions and vice versa in stations north of the Equator lags behind the sunrise and the sunset. At some stations south of the Equator, *e.g.*, Cocos Island, the opposite rule seems to be usual. These regular and universal diurnal variations have an average magnitude which is represented on the arbitrary scale used in the Forms by figures like 2 in the day and 5 at night in tropical latitudes, or 0·3 in the day and 3 at night in temperate latitudes. These figures are greatly affected by local meteorological conditions, which in fact frequently overwhelm all the statements set forth above.

Periods of Excessive Disturbance.

Occasionally the radiotelegraphic work at a station is rendered almost or quite impossible for a period, by strays of vigour and number greatly exceeding the average. These occurrences are for brevity called 'X storms,' the term 'X' being an alternative designation for 'stray' or 'atmospheric.' When an X storm happens in the day and lasts more than an hour or two, it may completely alter the character of the curve of that day's disturbances and even make the day portion of the curve higher than the night portion. An analysis of the records has shown that X storms occur within the same two or three days over very wide areas. Occasionally X storms are reported almost simultaneously at places several hundred miles apart, but more usually the X storms occurring at such distances are separated by several hours. Some of the European, American, and Canadian X storms have been compared with the meteorological records and charts for the two continents. The comparison has shown very plainly that periods of severe strays coincide with periods of low barometer, high wind velocity, rapid change of temperature, great rainfall, and, especially, rapid barometer fluctuations. In low latitudes the barometer fluctuations during violent X storms can usually be followed on any ordinary instrument. The worst X storm in the European records was accompanied by the rapid movement of a low-pressure system in a north-easterly direction. In twenty-four hours the eye of the cyclone moved from a point south-west of Lisbon to the North Sea, and in another twenty-four hours into

the Gulf of Bothnia. The worst X storm in the American records was also accompanied by the exceptionally rapid movement eastward from the Pacific of a cyclonic depression with steep pressure gradients. A report from a Californian station of the Marconi Wireless Telegraph Company of America on this latter occasion states that the barometer was fluctuating between 29·44 and 29·52 inches very rapidly, the variations being accompanied by gusts of wind which attained the velocity of 70 miles per hour. The disturbance produced in the telephones by the strays amounted to a roar. On this occasion, between 1 P.M. and night, the strays rapidly diminished as the wind fell and the barometer rose. These meteorological conditions are precisely those that accompany or precede thunder storms and line squalls; and, in fact, the records of the Meteorological Offices, and of the observers reporting to the Committee, all lead to the conclusion that X storms are often associated with thunder storms at places not very far distant. Sometimes all the symptoms of thunder weather except thunder and lightning may be present in a locality and a heavy X storm be recorded: *e.g.*, Mr. P. H. Burns, Superintendent of Telegraphs in the Bahamas, reports that he has often been experiencing an X storm when a sudden shift of wind to the north-west (wind velocity about twenty miles per hour) has taken place, and been followed by heavy rain, a calm, low temperature, lessened humidity, and a total disappearance of strays—all without thunder or lightning. To some extent these are symptoms of the passage of a small secondary or V depression such as might not be recorded on synoptic charts.

It is well known that the unstable atmospheric conditions bringing thunder weather sometimes move at a relatively slow rate from place to place, and may have their movements traced by the ordinary methods of meteorology. The analysis of the radiotelegraphic records shows that such convective weather can be anticipated several days in advance. This is particularly well borne out by some of the Malta records when taken together with some abstracts of the meteorological conditions kindly supplied by Dr. T. Agius, in charge of the Observatory at Valetta:—

Strays bad	All Aug. 22 and 23, 1914	Greatest rainfall of month Aug. 24.
,, ,,	Nights of Sept. 22 and 23 and day of 24	,, ,, ,, Sept. 25.
,, ,,	All Oct. 6 and 7	,, ,, ,, Oct. 9.
,, ,,	All day Nov. 12	,, ,, ,, Nov. 13.
,, ,,	Dec. 26 and 27	Greatest fall in temperature, lowest barometer Dec. 28.
,, ,,	Jan. 20, 1915	Greatest rainfall Jan. 21.
,, ,,	May 27 and 28, 1915	,, ,, May 31.

A report received from the wireless-telegraph station of the Government of Australia situated at Esperance states that during the day-time rain is preceded in at least eighty per cent. of cases by intermittent disturbances. Strays of varying strengths may be heard from 6 A.M. to

sunset for one or more consecutive days prior to rain. The following instances may be quoted:—

Feb. 13, 1915 . .	Strays strength	2A from 6 A.M. to 6 P.M.
Feb. 14, 1915 . .	„	3A from 6 A.M. to 10 A.M. and 4A from then till 5 P.M.
Feb. 15, 1915 . .	„	3A from 6 A.M. to 1 P.M. and 3C from 1 P.M. to 7 P.M.

On February 15, 16, 17 and 18, 167 points of rain were recorded, of which only 3 points fell on the 15th. On February 23, 1915, and strays were of strength 3A from 6 A.M. to 6 P.M. On February 24 129 points of rain fell.

This conclusion is borne out in other ways by some of the records forwarded to the Committee. There is evidence that north-west winds on our Atlantic coasts, especially in the winter, are associated with strong strays at Irish stations and at sea. The atmospheric convection produced by the land may be sufficient to account for this. Mr. R. Ricci, of the Marconi Company, who has made reports on two trips round the world, during which he made especially careful daily observations, states that in mid-ocean strays are, as a rule, very few and feeble both in the day and in the night; but that when the edge of a mountainous continent is approached strong, and even continuous, strays are normal. In this something must depend on the direction of the prevailing wind relative to the land—a matter that will be inquired into later.

It may be mentioned here as very significant that the months of the greatest X storms in the Mediterranean are shown by the records to be September and October, the months of cyclonic weather.

As a whole the statistics show that there appear to be two kinds of X storm occurring in the day-time: (1) Those produced by convective conditions in the atmosphere within, perhaps, a hundred miles of the station, which may be termed local X storms; (2) Those originating at a distance. Regarding the first class, they may occur almost simultaneously over a whole continent, but this is only because convective conditions happen to be ruling all over that area. Stations not too far outside the boundary of such a region also receive many strays, but apparently their distance must be limited to within 200 miles of the disturbed regions. In general, we may conclude that the observation of strays in the day-time constitutes a method of feeling the fringe of a region of convective weather, and so anticipating thunder and rain a day or two in advance. Of course, this ability to prophesy the advent of thunder weather is well known and is as old as wireless telegraphy itself; but hitherto it has been thought that the electric discharges at a great distance were responsible for the strays heard at the station attempting to prophesy. The present analysis indicates, rather, that at any rate in the day-time the strays are frequently due to very local discharges, often too weak to give noticeable lightning or thunder, but definitely indicative of an approaching period of instability in the atmosphere.

The second kind of X storm is not of strictly local origin, but is sometimes traceable in the stray observations made hourly at the Malta

station of the Eastern Telegraph Company, and the Sierra Leone station of the African Direct Telegraph Company. There is evidence that on certain occasions the same cause is affecting both stations though they are separated by 2,500 miles, mostly across mountain and desert.

As regards disturbances observed at night-time, these are also frequently very local and due to convective weather, but there is probably a greater proportion of non-local storms than appears in the day records. In this connection may be noted a report from Australian stations that the worst and most continuous type of disturbance (apart from local thunder storms) occurs on calm nights when the sky is blue and starry.

As a contrast to the prevalence of strays during convective weather may be instanced the fact, reported by Lieut. E. R. Macpherson from Sierra Leone, that a very dry wind which blows periodically for several days on the West Coast of Africa causes an almost complete cessation of strays immediately it starts and allows of their resumption immediately it stops. On the other hand, the monsoon period on the same coast is one marked by great X storms.

Correlation of Records at Distant Stations.

The daily records of strays received at the above-mentioned stations in Malta and Sierra Leone have been examined carefully for the period August 1914 to May 1915 inclusive. This period has been treated in four sections of two and a half months each. It will be sufficient to give the following figures, which refer to the night hours 10 P.M. to 2 A.M., Greenwich mean time:—

M. indicates Malta, S. L. indicates Sierra Leone.

Mean M.	14·13	14·24	12·85	13·70
Probable error . .	±·64	±·67	±·57	±·53
Mean S. L. . . .	28·68	19·90	14·87	26·31
Probable error . .	±·69	±·78	±·68	±·68
Standard Deviation, M. .	8·34	8·66	7·28	6·78
,, ,, S. L.	8·94	10·17	8·77	8·79
Correlation Coefficient .	0·18	0·36	0·14	−0·25
Probable error . .	±·075	±·067	±·075	±·073

Graphic Records.

Many observers have made for the Committee precise observations of individual strays by making, on lines graduated to represent time, marks corresponding to each stray as heard in the telephones, the zero of time being fixed by aid of radiotelegraphic time signals within range of the observer. Comparison of the records made in the British Isles has shown that on an average night many of the strong strays are heard by all the observers, and on days free from X storms the same remark applies. Coincidences have also been noticed between pairs of American stations not too widely separated. The analysis for very distant stations has not yet been carried out except for a very few in Europe. For example, in the month of June 1914, coincidences have been traced in the strays heard at Southampton and Dresden, Gibraltar and Dresden,

Guildford and Malta. A proper investigation of the meteorological conditions accompanying or determining the periods when strays are heard simultaneously at places very wide apart has not yet been made.

Auroral Displays and Strays.

By the kindness of General Geo. P. Scriven, Chief Signal Officer of the United States Army, the Committee have been able to obtain reports from Officers in the Wireless Telegraph stations of Alaska concerning the presence or absence of any connection between auroral displays and disturbances due to natural electric waves or atmospheric discharges. At six stations special observations have been made during the later months of the past winter. Various types of aurora were watched, but nearly all the observers reported that the appearance or disappearance of auroræ caused no unusual disturbances. The best months for such observations in Alaska would, it is stated, be October and November. The systematic work had not then been started, but one telegraphist reports that during this period of more brilliant display the only thing noticed in the radiotelegraphic apparatus was a trifle more electrical disturbance than occurred when there was no aurora.

The 27-day Period of Magnetic Variations.

Such of the radiotelegraphic records as were suitable for the purpose have been analysed with a view to detecting a 27-day period in the cases: days with many strays, nights with many strays, nights with few strays. No trace of this period or of any nearly equal period has as yet been found, but the matter cannot be regarded as settled till more numerous and more continuous records are available.

The Committee desire to express their cordial thanks for the help extended to them by the Government Departments, companies, and private individuals named below. The list refers to those whose co-operation has been of importance in the matters described in the preceding pages, and does not include the names of those who have helped in other investigations. The assistance of the latter will be duly acknowledged in future Reports.

The British Admiralty and Post Office; the Colonial Office; the Governments of Australia, Canada, and New Zealand; the War Department and the Navy Department of the United States of America; and the Telegraph Department of the Dutch East Indies; the Marconi Companies in England, Canada, and the United States and the Marconi International Marine Communication Company; the Eastern Telegraph, Eastern Extension, and African Direct Telegraph Companies; H. Barkhausen, W. G. Cady, E. T. Cottingham, D. O. Davies, E. H. Dixon, E. D. Evens, J. P. Fennelly, A. Gorham, F. Kilbitz, J. R. Lamming, L. H. Lomas, F. A. Love, E. R. Macpherson, T. J. Matthews, W. E. Nicoll, F. E. Norris, R. Ricci, D. Rintoul, C. Ross, A. Hoyt Taylor.

Establishing a Solar Observatory in Australia.—Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Professor W. G. DUFFIELD (*Secretary*), Rev. A. L. CORTIE, Sir F. W. DYSON, *and* Professors A. S. EDDINGTON, H. F. NEWALL, J. W. NICHOLSON, *and* A. SCHUSTER. (*Drawn up by the Secretary.*)

THE visit of the British Association to Australia was made the occasion for further representations to the Commonwealth Government of the urgency of Australia's co-operation in the work of solar observation. The previous report of the Committee contained the official announcement from the Commonwealth Government that in the scheme for the organisation of services in connection with the Seat of Government at Canberra provision had been made for the study of Solar Physics. The Prime Minister received a deputation of members of the Committee upon matters relating to the institution of this work in the Commonwealth.

Professor ORME MASSON, in introducing the deputation, referred to the world-wide interest taken in the movement to establish a Solar Observatory in Australia, and to the fact that so many British astronomers had joined the party to Australia in spite of the counter-attractions of a total solar eclipse in another part of the world.

The ASTRONOMER ROYAL said that he had, with others, urged upon Mr. Batchelor the importance of sun work in Australia where suitable facilities existed for its study apart from other astronomical questions. Australia was most favourably situated geographically; he hoped that the visiting astronomers would be able to leave Australia with the assurance that, as soon as the war was over, the Observatory would be a going concern.

Professor TURNER stated that one of the prime factors in determining his acceptance of the Commonwealth's invitation to visit Australia was the prospect of assisting in founding a Solar Observatory in that country; he stated that, though a promise of an observing station in New Zealand had been made, solar radiation could not be undertaken there, and, further, there was urgent need for solar physics investigations to be made further north. They had been regarding the sun too long as a permanent source of light and heat; all the tendencies of modern science went to show the opposite—that it presented variations, an inquiry into which might be of immense value to agriculture. Discussions with his astronomical colleagues had been embarrassed by the war, which had made it seem doubtful whether it was the right moment to ask anybody for anything at all; but while it was obvious that immediate action might be impossible, it seemed undesirable to lose the opportunity of putting on record the views of visiting astronomers and their enthusiasm for this great project. He hoped that the present observatories in Australia would not be disturbed.

Professor ABBOT said that prior to ten years ago no knowledge existed of the energy of the sun, or of the intensity of its radiation. Its variation ranged to as high as 5 and 10 per cent. Solar observatories had been established in California and Algeria, and they should be multiplied in different parts of the globe. In Australia there was a clear, unvarying transparency in the air which was particularly adaptable. It was hoped that the work would be extended to South America, Africa, and India. The approximate cost of installing radiation apparatus at the Australian station was 2,000*l.*, and the maintenance about 1,300*l.* a year.

Sir OLIVER LODGE urged that if the work was to be attacked in Australia it should be done thoroughly, and emphasised the desirability of associating laboratory work with that of solar observation. The British Association for the Advancement of Science had for many years strongly supported the institution of solar research in Australia, and it was a matter of great satisfaction that there was now a prospect of the fulfilment of the international scheme.

Professor DUFFIELD outlined the support already accorded by the Commonwealth towards the scheme for the institution of solar work in Australia, referring in particular to the support given by Mr. Mahon and Mr. Deakin, the latter of whom in 1909 offered 1,500*l.* per annum towards this institution if the equipment were forthcoming from other sources. The Commonwealth had subsequently accepted the telescope offered by Mr. Oddie, of Ballarat, and the Farnham telescope. The former had been installed at Canberra and the latter had now been brought to Australia, and, on receiving the assurance that the Government intended to proceed with the project at an early date, the instrument would be handed over to the Commonwealth.

A sum of money amounting to upwards of 1,500*l.* had been subscribed towards the purchase of other apparatus for the Solar Observatory; this had been offered to the Commonwealth, but for some reason had not been accepted. Should there be any disposition on the part of the Commonwealth to undertake to make use of this apparatus, the offer of it would be repeated. He did not believe that the institution of a Solar Observatory in New Zealand should deter the Commonwealth Government from undertaking this work, since both institutions were required.

The Hon. ALFRED DEAKIN (late Prime Minister of Australia) stated that he was in sympathy with the objects of the deputation. When the matter was brought before him on a previous occasion he had supported it, as other speakers had stated. He was not sure what the Prime Minister would feel should be done in view of the situation created by the war, but trusted that all that was possible would be done to further this scheme.

Mr. JOSEPH COOK (the Prime Minister), in reply, said that he would like to accede to the wishes of the deputation at once; it appeared to him that the matter was one deserving of attention, and if times were normal he would not hesitate to have a sum placed upon the Estimates for the establishment and upkeep of such an institution. It had been part of the policy of the Government to consider whether they could do

away with the State observatories and combine them all in one central observatory for Australia; he would like to hear the reasons why that should not be done. Present war obligations precluded voting large amounts; he would see, however, how far the matter could be carried, and would promise that one of the last things to be set aside on the score of economy would be the suggestion made by the deputation.

In addition to the speakers, Professors E. W. Brown, A. S. Eddington, and J. W. Nicholson supported the deputation, and Mr. Baracchi, Government Astronomer for Victoria, wrote a letter strongly emphasising the need for solar research in the Commonwealth, and expressing the opinion from personal observation that Canberra would prove a suitable site.

The Secretary of the Committee was subsequently invited to discuss the matter with the Prime Minister, with the result that estimates were drawn up for making a beginning of the institution. These and the offer of apparatus mentioned at the deputation were the subject of discussion at a Cabinet meeting, the outcome of which was the following letter:—

COMMONWEALTH OF AUSTRALIA.

Prime Minister.
Melbourne, Aug. 20, 1914.

DEAR SIR,—With reference to our interview relative to the question of establishing a Solar Observatory and to the offer made by you to hand over immediately to the Commonwealth one Farnham 6-inch telescope—the Commonwealth paying freight and packing charges—also later on to present to the Commonwealth one spectroheliograph and one pyrheliometer, both of which have yet to be purchased with funds collected and in your charge, I desire to inform you that the Commonwealth Government has much pleasure in accepting the instruments so kindly offered, and appreciates the public spirit of the donors. No guarantee, however, can be given when a Solar Observatory will be established beyond saying that when times are more favourable the instruments will be erected in an appropriate building and observations conducted. Meanwhile the instruments will be carefully housed and looked after.

Yours faithfully,
(Signed) JOSEPH COOK.

Professor W. G. Duffield, D.Sc., Sydney.

Upon receipt of this letter Professor Duffield handed over to the Commonwealth the Farnham telescope, which had been offered in 1908 by the late Mr. W. E. Wilson on behalf of the trustees of the late Lord Farnham. The telescope has been temporarily housed at the Melbourne Observatory by the Commonwealth authorities.

Subsequent to Mr. Cook's relinquishing office the present Government, under Mr. Fisher, has taken over the obligations entered into by Mr. Cook and Mr. Deakin, and has defrayed the cost of freight, package, and repair of the Farnham telescope, and also has made provision for an Evershed spectroscopic attachment, amounting in all to 100*l*.

Other activities by members of the Committee were displayed by a

discussion following upon the reading of the last Report of the Committee in Melbourne, which was reported in the Australian papers; and by a vigorous reply to a newspaper criticism by the Chairman. The Committee also wishes to draw attention to the valuable report upon the site of the Observatory at Canberra written by Mr. Baracchi, of which a brief account was read to the Association in Melbourne.

Though the war will necessarily delay the institution of the Solar Observatory at Canberra, the Committee trusts that its efforts have met with a measure of success.

Determination of Gravity at Sea.—Interim Report of the Committee, consisting of Professor A. E. H. Love (*Chairman*), Professor W. G. Duffield (*Secretary*), Mr. T. W. Chaundy, Sir F. W. Dyson, Professor A. S. Eddington, *and* Professor H. H. Turner. (*Drawn up by the Secretary.*)

It was decided by the Committee of Section A that advantage should if possible be taken of the voyage to Australia for the 1914 Meeting of the British Association to undertake a series of observations upon the determination of the value of gravity over the ocean. The main object of the research was to test the compensation theory, or theory of the isostatic layer, in regard to the distribution of matter in the superficial portions of the earth. The Secretary to the Committee undertook to make an attempt to solve the problem, and upon the advice of the Chairman wrote to Professor Hecker, who had previously undertaken some important researches in this respect.

Professor Hecker advised that six months' preparation would be insufficient to enable an experimenter to accumulate the apparatus and become *au fait* with the technique of the method which he had employed in 1901 and 1904—*i.e.*, the comparison of a mercurial barometer with a boiling-point apparatus for determining the atmospheric pressure. But after consultation with Professor Helmert he invited the Secretary to test a new piece of apparatus which he had had constructed for the determination of gravity at sea, and which he had not previously had the opportunity of testing. This depends upon balancing a column of mercury against air enclosed in a vessel and maintained at a constant temperature. The Secretary regretfully accepted Professor Hecker's dictum concerning the undesirability of attempting to repeat the experiments by the boiling-point method, but gratefully accepted his offer of the opportunity to test the new piece of apparatus. A feature of the new method being the constancy of the temperature of the air reservoir, it was necessary to carry out the experiments in the refrigerator of a vessel. The Secretary was fortunate in obtaining the permission of Messrs. Alfred Holt & Co., of the Holt Line of steamships, to make use of the refrigerator on board the Steamship *Ascanius*, which was sailing from Liverpool on June 22, 1914. By invitation, he inspected the refrigerating chambers on a sister ship, as the *Ascanius*

was then in foreign parts, and Messrs. Holt, who accompanied him, offered very kindly to install a special chamber upon the *Ascanius* immediately upon her return to home waters, for the purpose of these experiments. This generous offer was accepted and a chamber built which was capable of separate temperature regulation and fitted with certain necessary conveniences for the research. It is not proposed, in the Interim Report, to describe this laboratory—that is reserved for the main Report, which, it is hoped, will be completed shortly.

In order to gain a first-hand knowledge of the method of using Hecker's apparatus, it was decided that the Secretary should visit Professor Hecker's laboratory in Strassburg as soon as the necessary calibration of thermometers and general overhauling of the apparatus had been accomplished. Unfortunately this took longer than was expected, as four new thermometers had to be made, and Professor Hecker was not able to wire that all was ready until three weeks before the date of sailing. After five days with Professor Hecker the Secretary returned to England, bringing with him the barometers and thermometers and leaving five cases to be despatched direct to the *Ascanius*. The glass parts were safely conveyed by hand to Reading, and subsequently to the ship in Liverpool. It was extremely unfortunate for the success of the experiment that there was no time for assembling and testing the apparatus before the ship sailed. Although Messrs. Holt placed their joiner and two carpenters at the continuous disposal of the experimenter for three days before the ship sailed, and though Dr. Sadler had come from Reading to assist in this work, it was not found possible to get the apparatus installed and the final adjustments made before the ship sailed. At first the variations in the temperature of the special chamber afforded some trouble, but, thanks to the kind collaboration of Captain Chrimes and the chief engineer, Mr. Douglas, it was arranged with the refrigerating engineer, Mr. Latham, that the temperature of the chamber should be adjusted at intervals of about twenty minutes during the day-time and one-hour intervals during the night. The results of this frequent adjustment will be shown in the final Report. It does credit to Mr. Latham's devoted attention. The Committee records its appreciation of their services to the captain and engineers of the *Ascanius* and to Messrs. Alfred Holt for having placed all their resources at the disposal of the experimenter. Unfortunately, Hecker's apparatus did not prove satisfactory, because it was discovered late in the voyage that all four barometers had developed leaks. It was hoped at the time that these leaks had only developed during the rough weather which preceded their discovery, but subsequent careful examination of the results has shown, unfortunately without any possible doubt, that the barometers were never air-tight. This is perhaps not very surprising considering that each barometer includes six metal to metal joints, three glass to metal joints, and one glass tap, and that the strains at sea are very considerable. After a consultation with some of the members of the British Association on the *Ascanius*, it was decided that the only hope of making successful use of Hecker's apparatus was to coat each barometer with a heavy layer of wax. During the comparatively calm weather which preceded the ship's

arrival at Fremantle two of the barometers were opened and closed again, and sealed with all the wax which could be found on the ship. The remaining two were similarly treated at Fremantle with paraffin wax purchased at that port. Disappointed at the nugatory results of these experiments, the Secretary, who had previously made arrangements to return *via* Suez, now decided to abandon that route and to repeat the experiments on the homeward voyage round the Cape of Good Hope on board the *Ascanius*, as the captain and engineers expressed their willingness to assist. Unfortunately these arrangements had also to be abandoned, because, with the arrival at Adelaide, came the news of the outbreak of war, and the ship was eventually requisitioned by the Government It was not possible to obtain permission to return with the troops and to make use of the refrigerator, so it became necessary to find some other means of returning with the apparatus. Up to the time of the British Association meeting in Melbourne the work had been done by Dr. Duffield upon his own responsibility, but, at that meeting, the Committee was formed of which this is the Interim Report. The Committee expressed its hope that if possible the experiments should be carried out on the return journey, so after numerous inquiries and interviews with shipping authorities the Secretary was given permission to install his apparatus in the refrigerator of the R.M.S. *Morea*. The Committee is indebted to the Superintendent of the P. and O. Company in Sydney for encouraging this research, and to the purser of the *Morea* (Mr. Owen Jones), but it was the goodwill and the assistance which the ship's butcher and his mate gave on the voyage which rendered it possible under very adverse conditions to take advantage of the permission which had been given and to make an attempt to carry out this research upon the homeward voyage.

In the first place it was necessary to construct a laboratory in the depths of the ship's refrigerator (which was approached by three nearly vertical ladders). This was accomplished by the ship's carpenters through the courtesy of the Chief Officer; the wiring for the electric fan and lights was carried out by the Electrical Engineers of the ship. The next care was the packing up and removal of the apparatus from the refrigerator of the *Ascanius* and its conveyance to the *Morea*. The breakables were carried by hand and the heavier parts by carrier. The whole operation lasted one week, and the transference was successfully accomplished. The barometers were unsealed, opened, closed, and resealed and heavily coated with wax in Sydney harbour. During the homeward voyage, as during the outward one, observations were made on an average three times a day, and the films were developed on the voyage. Unfortunately, the same facilities for controlling the temperature were not available on the *Morea*, and on some occasions the fluctuations were very remarkable. Another disadvantage, as far as this experiment was concerned, was the vibration, which threw the surface of the mercury into a constant state of agitation and which could not effectively be damped; nevertheless, observations usually of an hour's duration were carried out three times a day during the whole voyage. It was regarded as unfortunate that the experiments could not

is one of the many researches which have suffered on account of the favourable conditions as attended their conduct on the *Ascanius*. This is one of the many researches which have suffered on account of the war.

In addition to the main line of attack it was considered of interest to repeat a method which had been used in 1866, when the readings of mercurial and aneroid barometers were compared. Mr. Whipple, of the Meteorological Office, has described the aneroid which the Cambridge Scientific Instrument Co. kindly lent the experimenter for this occasion (*vide* 'Journal Royal Meteorological Society') and the Meteorological Office kindly lent a dial mercurial instrument. A criticism of this method will appear in the main Report. Messrs. Cossor constructed to the design of the Secretary a third piece of apparatus in which, as in Hecker's method, a column of mercury was balanced by the pressure of air in a reservoir, but it was arranged that the volume of air could be kept constant by introducing into or removing from the vertical column a quantity of mercury whose volume could be measured. In spite of the efforts of the Secretary and of Dr. Sadler, whose assistance in installing the apparatus in the refrigerator laboratory is very gratefully recorded, it was not found possible to get this last piece of apparatus into working order before the ship sailed; during the voyage this was accomplished, but the working loose of a glass tap, though bound with an india-rubber band, let air into it, causing the glass to break. Experimenters with glass apparatus may be warned that on board ship the constant vibration imposes conditions foreign to those pertaining to their laboratories ashore. Through the courtesy of Professor Kerr Grant, of the Adelaide University, the workshop of the Physical Laboratory of that institution was placed at the disposal of the Secretary for the repair of the apparatus, but in spite of the efforts of Mr. Rogers, the head of the workshop department, whose skill as a glassblower enabled him to reconstruct the apparatus, it was not found possible to get it adjusted before the time came to re-embark upon the homeward voyage.

In conclusion, it is to be feared that results capable of determining the fluctuations of gravity over a large surface of the globe have not been obtained. The most that can be hoped for is that local variations, such as obtain when one passes from deep water into a shallow harbour, may have been at favourable times determined. It cannot, however, be doubted that the experience gained of the different kinds of apparatus, and of the various errors to which they are liable, will be of service in some attack upon the problem which it is hoped that the Committee will undertake in the near future.

Seismological Investigations.—Twentieth Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Professor J. PERRY (*Secretary*), Mr. C. VERNON BOYS, Mr. HORACE DARWIN, Mr. C. DAVISON, Sir F. W. DYSON, Dr. R. T. GLAZEBROOK, Mr. M. H. GRAY, Professor J. W. JUDD, Professor C. G. KNOTT, Sir J. LARMOR, Professor R. MELDOLA, Mr. W. E. PLUMMER, Professor R. A. SAMPSON, Professor A. SCHUSTER, Mr. J. J. SHAW, Sir NAPIER SHAW, *and* Dr. G. W. WALKER.

[PLATES I., II., III., IV.]

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I. *General Notes, Stations, and Registers.*

THE Committee asks to be reappointed with a grant of 60*l.* in addition to the annual grant of 100*l.* from the Caird Fund already voted.

The two years which have elapsed since the death of John Milne provide a sufficient experience for an approximate budget for carrying on the work he had organised, with such natural developments as are mentioned below and had already been initiated by him. The accounts for one year stand thus :

Receipts.		*Expenditure.*	
(1) Brit. Assoc. Annual Grant	£60	(A) Salaries	£240
(2) „ „ Printing	70	(B) Printing	80
(3) Gray Fund	40	(C) Rent	20
(4) Royal Society	200	(D) Shide Station	65
(5) Brit. Assoc. (Caird Fund)	100	(E) New machines, &c.	65
Total	£470		£470

On the receipts side the items are arranged in historical order. Item (1) dates practically from the appointment of the present Committee (as the fusion of two former Committees of the Association) in 1895 (Ipswich). The first grant to the Committee was 80*l.* Subsequent grants have fluctuated in amount, but the average annual grant in the twenty years 1895–1914 is almost exactly 60*l.*, which has been the uniform grant since 1908. When observing stations had been established over the globe

and it was desirable to print the information received from them in circulars for prompt distribution, the Association sanctioned additional expenditure on the printing of these circulars, which has in recent years been separately mentioned and has stood at the figure quoted—70*l.* This does not quite cover the cost of the modern bulletins.

Item No. (3) is the annual income from a sum of 1,000*l.* in Canadian Pacific 4% Stock, presented by Mr. M. H. Gray in aid of Milne's work.

Since some years before Milne's death, the Royal Society have provided, either from the Government Grant Fund or in some other way, an annual sum of 200*l.* in aid of the work. They have continued this grant during the past two years, but are in no way committed to its future continuance. On Milne's death the Council of the British Association decided to make an additional grant of 100*l.* annually from the Caird benefaction.

It will be seen that the available income is not only small but somewhat precarious. It is quite insufficient to pay the salary of a competent Director, which would in itself amount to more than the whole sum available. Moreover, items (1), (2), and (4) depend on decisions made from year to year by bodies which are not committed for their future continuance.

Assuming that continuance for the present, the work can be carried on as described below with voluntary superintendence.

For completeness it should perhaps be mentioned that a sum of 1,000*l.* will ultimately be available for seismological work in accordance with Milne's bequest.

On the expenditure side item (A) chiefly represents the salaries of three people who carry on the work at Shide, viz., Mr. J. H. Burgess (126*l.* a year), who was already working under Milne's direction. He has a printing business in Newport which claims a portion of his time; the rest he has given enthusiastically to seismology. It is practically owing to him that the continuity of the work remained unbroken by Milne's death. Mr. S. W. Pring (60*l.* a year) is also in business, but spends his evenings at the Observatory. His interest in the work began through his knowledge of Russian and other languages, which made his help valuable in translating seismological documents, especially the important pamphlets in Russian; but he has gradually made himself acquainted with the whole of the work, so that he can take charge of it on occasions when Mr. Burgess is unavoidably absent. His daughter, Miss K. Pring (36*l.* a year), gives practically all her time to the work during the day; she is chiefly occupied with the large amount of clerical work involved in copying the records received on to the cards, arranging the cards for the bulletins, proof reading, &c.

This leaves 18*l.* out of the 240*l.* entered, chiefly travelling expenses of the present Director, who visits Shide five or six times a year; the remainder being paid to a charwoman for cleaning, &c.

Item (B). The 'Shide Circulars,' which simply reproduced the information received from each station, have been replaced by Bulletins which analyse the results. Expense has been minimised by printing only the results for considerable earthquakes, but even then it is difficult to avoid exceeding slightly the grant definitely available for printing.

Item (C). The rent for the Observatory was fixed by Mrs. Milne's trustees, after consideration of the legal aspect of the question. The

Observatory is annexed to the house in which Mrs. Milne continues to reside, and the Committee has to acknowledge gratefully her kind occasional attention to Observatory matters. The assistants who work in the Observatory all live at a distance, and arrangements are sometimes much facilitated by the help of some one residing on the spot.

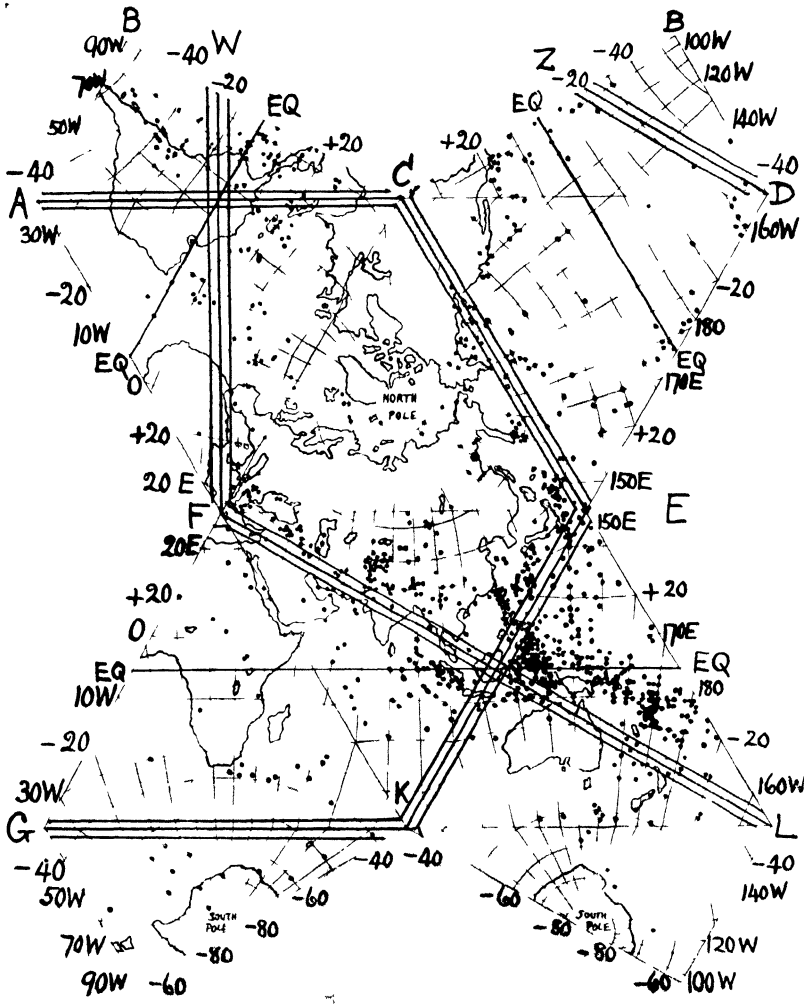
Items (D) and (E) are not readily separable because during the past two years part of the work at Shide has been to experiment with new instruments, as described below. Looking backward, item (E) covers expenditure on three or four new machines; the first, constructed by Mr. Shaw at Milne's request and delivered soon after his death, was satisfactorily 'damped' but had not sufficient magnification. To get more magnification, Mr. Shaw preferred to make a new machine rather than alter the former. Meanwhile, Mr. Burgess, with the kind help of Mr. A. E. Conrady, devised another type with optical magnification (instead of mechanical as in Mr. Shaw's), which is being tried side by side with the former. Finally, a Milne-Shaw machine has been made for trial at Eskdalemuir alongside the Galitzin and Wiechert machines. Looking forward it is hoped that at least some such sum as item (E) may be available annually for replacing the existing Milne machines, which scarcely meet modern requirements. The conditions under which many of them were established will be found described in the 1898 Report (Bristol), p. 179. The original Shide instruments were provided from the Government grant; later an improved twin-boom Milne was provided by the generosity of Mr. Yarrow; the Victoria (B.C.) instrument from the British Association grant (Toronto, 1897), which also provided half the cost of the Mauritius instrument. Other machines were provided by various Governments, observatories, and individuals, but it seems doubtful how far their aid can be again invoked in this way, at any rate until the advantages and working of an improved type of instrument have been demonstrated by a number of good examples.

II. *Stations.—Destruction of Instruments at Cocos.*

A letter, dated April 1, 1915, from Mr. Walter Judd, Electrician-in-Chief of the Eastern Extension, Australasia and China Telegraph Company, informed us that: 'the Seismograph installed at our Cocos Station was destroyed by the landing party from the *Emden* last November.' On April 12 a further letter from the General Manager communicated the following telegram from the Company's Manager at Singapore: 'Meteorological insts. destroyed by *Emden*, Singapore advised 27 March, Straits Government intend replace.'

Probably the replacement must wait for more peaceful times. The Cocos installation dates from 1909, and is due to the generosity of the Company.

New Station at Newport (*I. Wight*).—In recent bulletins it will be noticed that besides the Shide Station, one at Newport is quoted. This is the station of Mr. W. H. Bullock, a builder in Newport, who did much work for Milne, became keenly interested in Seismology on his own account, and has devised an instrument of his own, with Milne suspension, smoked paper drum and high magnification. It shows the beginnings of the various phases very beautifully. At present there is no damping beyond the friction of the point on the smoked paper, which is effective for small movements, but not for large. Mr. Bullock is experimenting with electro-



Earthquakes recorded by Milne 1899–1910
Small Islands which might be mistaken for dots, have been omitted

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magnetic damping, and if he is successful it is proposed to order an instrument from him for use at Shide. It will be especially useful (1) in showing when there has or has not been an earthquake, for guidance in changing the paper of the photographic machines, and (2) for showing to the numerous visitors to Shide the working of a seismograph without disturbance of the photographic machines. In both respects it will replace the large 'lamp-post' machine formerly set up by Milne, but discontinued as too cumbersome.

Time Signal at Shide.—On the outbreak of war, the wireless apparatus used for receiving the time signal from the Eiffel Tower was dismounted in accordance with instructions from the Post Office, and for some months it was difficult to obtain correct time In December 1914 a small transit instrument, lent by the Royal Astronomical Society, was set up on a disused seismograph pillar near the south window and adjusted as well as possible with a view restricted to altitudes less than 45°. With the kind help of a few telephone exchanges from the Royal Observatory, Greenwich, this sufficed to give clock errors until May 1915, when the Post Office permitted the re-erection of the wireless apparatus. From May 20 this has accordingly been in use again, and has confirmed the accuracy of the transit determinations. On July 23 a storm blew down the aerial, but it was re-erected next day.

While the apparatus was dismounted and clock error being found by the small transit, Mr. J. J. Shaw visited Shide for regulation of his seismograph, and incidentally compared the Shide clock with his watch, of which he knew the error and rate. To his surprise a large discrepancy developed between the two, and it became clear that the watch was at fault. The cause was traced to the suspension of the watch during the night, which allowed of its vibrating as a pendulum. Attention was drawn to this matter by Lord Kelvin many years ago, but the magnitude of the possible error has scarcely been realised sufficiently. Mr. Shaw recalled attention to the matter, which is of considerable practical importance, in a short paper to the Royal Astronomical Society ('Mon. Not.' lxxv., p. 583).

III. *Seismic Activity in* 1911, 1912 *and* 1913.

Milne carried the list of origins to the end of 1910. From the beginning of 1914 the origins of the larger earthquakes have been specified in the monthly bulletins, at first adopted from the Pulkovo determinations, and later, when it became clear that these could often be profitably corrected, adopted from special determinations made at Shide. The corrections are partly due to errors of the tables, estimated approximately at the end of the last Report, but still under revision. It seemed desirable to await these corrections to the tables before undertaking the computation of origins for 1911–13; but these will shortly be commenced.

IV. *Distribution of Milne's Epicentres*, 1899–1910.

In the last Report a map of the world was given on an octahedral projection, the precise selection of which had been suggested by the study of the epicentres tabulated by Milne for the years 1899–1910. The work of plotting the individual epicentres on this map had not then been completed. When complete (as shown in the acompanying illustration) it showed that the root-idea of the map did not fit the facts in its

original form. The edges of the eight triangles form three great circles at right angles, and it was expected that the epicentres would cluster about these edges. But only one of these great circles, GKECA, fulfils this expectation. Of a second, LKFCD, it was already remarked in the last Report that it was not at present a conspicuous line of earthquake activity, but that the geographical features characterising it (the Red Sea, Italy, the Alps, the American Lakes, California) suggested such activity in the past.

The principal change required by the hypothesis as stated in the last Report concerns the third great circle, which is formed by EF and the boundaries of the map. For this we must clearly substitute a great circle LFW, with ZD, which falls midway between the two now discarded. This makes the general hypothesis really simpler than before, substituting two circles, still at right angles, for the three formerly suggested, and retaining many of the important features of symmetry. The two circles retained have been indicated by a triplet of lines. (A thick line would have obscured some of the epicentre dots.)

The third circle cutting both these at right angles would be along DF, then F to the South Pole, and South Pole to L. There is something to be said for including this in the system, but it does not account for much that is not already accounted for by the other two, so that for the present we may omit it.

We could, of course, suit the great majority of epicentres better by drawing, instead of FL, some line nearer to E; and, instead of FW, some line nearer to C. This means leaving the great circle and substituting some small circle. 'Libbey's Circle,' which was drawn by Milne on the earthquake maps in the Reports for 1903–1909, is approximately a small circle parallel to WFL, at about 20° from it, and would suit the facts very well. But the elementary simplicity of the hypothesis is then lost, and it seems preferable to retain the simple form above indicated for comparison with future facts; and perhaps even with a revised version of the facts already used, for the determinations represented on the diagram are of different values—in some cases well established, in others very uncertain.

V. *Improvements of the Milne Seismograph.*

Section IV. of the last Report is devoted to a discussion of the times recorded by different seismographs for the beginning of P and S. It is shown that while the probable error of the Milne instrument is distinctly greater than that of modern instruments, the favourable geographical distribution of these pioneer seismographs renders them still capable of giving valuable information. At the same time it is clear that the time has arrived when it is desirable to give the Milne seismographs

(*a*) a higher magnification;
(*b*) some form of damping.

The former consideration is put first because seismology is at present very definitely concerned with the determination of the times of arrival of P and S. Not only do the tables for these times of arrival require corrections, but it seems probable that the phenomena themselves are not always rightly identified. It was pointed out that at distances from

the origin exceeding 90°, PR is often reckoned as P; and it seems at least possible (see Section X) that some hitherto unrecognised phenomenon is sometimes mistaken for S. This was foreshadowed in the last Report from the fact that, though the magnitude of S is usually much greater than that of P, so that its identification might be presumed to be much easier on the whole, nevertheless the probable error of the observed time of arrival of S is considerably greater than that of P. If some other phenomenon is liable to be mistaken for S, this larger probable error is easily explained. Briefly, the proper interpretation of the seismograph trace is essentially dependent on a proper identification of the times of arrival of P and S; so that for the present attention may be profitably concentrated on this problem. It is important to increase the magnification considerably, because the waves of P are particularly small and difficult to pick up; further, it becomes necessary to provide such magnification that these small movements shall not be blotted out when damped. The importance of damping is second only to magnification, for probably much of the uncertainty in reading S is due to the inability of free pendulums to record the change in character of the ground movement in this phase.

As remarked above, two new forms of the Milne pendulum have been constructed for trial by Mr. J. J. Shaw and Mr. J. H. Burgess, and brief notes on the details are given in the next two sections.

VI. *The Milne-Shaw Seismograph.*

(*Note by* Mr. J. J. Shaw.)

This is a new type of seismograph with high magnification, combined with absolute damping. The magnification is approximately forty times greater than the standard Milne.

It is an established fact that only fully damped machines give any approximation to a true record of the ground movement; moreover, with damping, the various phases, P, PR, S, SR, and Max, are much more readily determined; this will be realised by comparing the undamped records with those of the Milne-Shaw for Nov. 24, 1914, illustrated on Plate II.

The Milne-Shaw gives a record strictly comparable with that of a Galitzin,* but with this distinction, that the latter depends upon and gives a measure of the velocity, whereas the former gives a direct measure of the amplitude of the ground movement, and does not involve the use of a galvanometer.

The general principle of the apparatus is to multiply the movements of a short damped boom by reflecting a beam of light by means of a pivoted lens of half a metre focal length.

The boom (16 inches long) carries a mass of 1 lb., together with a damping vane which moves in a strong magnetic field, and brings the boom to rest after each excursion.

The outer end of boom is coupled to an iridium pivoted mirror, which it rotates in an agate setting; by this means 300 multiplications of the ground movements are obtained. The definition in the trace is a special feature in this machine. The source of light illuminates a vertical cylindrical lens, and the image created is reflected and refocussed by the pivoted reflecting lens on to a second cylindrical lens placed hori-

* Compare illustrations Plate II. and page 70.

zontally, which again refocusses the light into a small intense point. This point falls midway upon a slit ·003 in. wide and only the middle portion is permitted to pass to the film, which is in immediate contact with this slit. Perfect definition is produced in this way, with the result that waves of not more than two or three seconds period are shown quite distinctly on paper moving only 8 mm. per minute, thereby securing both high efficiency and economy.

Special calibrating and adjusting devices were necessary with such high magnification. This has received special attention, and tilts of 1/100 of a second of arc can be applied and registered by a beam of light on a distant calibrating scale. All such operations are performed at a distance from the column, the motion being transmitted by a long flexible cable, so that the movements of the observer shall not enter into the amplitude shown in the trace.

VII. *The Milne-Burgess Seismograph.*

(*Note by* Mr. J. H. Burgess.)

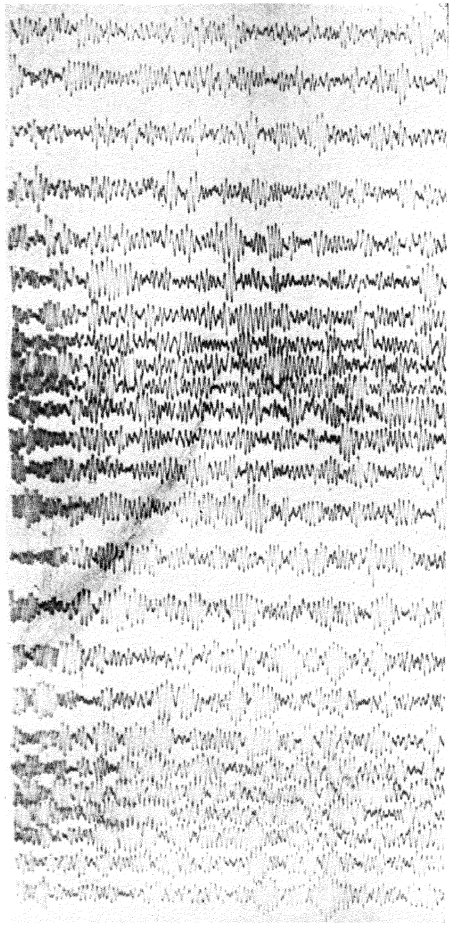
The Milne-Burgess machine is a modification of the Milne horizontal pendulum, the chief differences being a magnification of 100, about 75 per cent. of artificial damping, and an increased rate of travel.

The registration is photographic. A collimator with a 2 in. objective and 21 in. focus is mounted to produce a real image of an illuminated glass rod 1 mm thick at a distance of 10 ft. from the object glass. The illuminated line is reflected by means of a piece of sextant mirror attached to the boom just behind the balanced weights through a hole in the wall on to a recording box in another room. In front of the drum a plano-convex cylindrical lens of $\frac{1}{2}$ in. focus is fixed. Behind this lens is a fine horizontal slit, and in this way the reflected line of light is brought to a focus on the recording drum The drum has a circumference of 40 in. by 6 in. wide, and travels at the rate of 480 mm. per hour. Accurate time-marks are put on the trace every minute by an electric shutter operated by the Observatory clock.

The boom has balanced weights and is artificially damped by means of a copper plate attached to the end of the pendulum which moves between four magnets as shown in the sketch. The induced currents produced when the plate moves retards the motion, and in this way about 75 per cent. of damping is introduced. By the employment of stronger magnets periodicity could be obtained.

VIII. *Diurnal Wanderings of the Traces.*

The introduction of a high magnification has brought with it an inconvenience in the unsteadiness of the trace. The trace at Bidston, which with the Milne instrument was a series of smooth lines at equal intervals on the paper, became at once, with the Milne-Shaw, a series of rippling lines crowded in two places and wide in between, the unequal spacing being obviously due to tidal action, and the ripples, the period of which is of the order of 10 sec., being such as appear to disturb all highly magnified traces. At Bidston these ripples appear definitely to be due to wind; at any rate on a windy day they are largely increased, as will be seen from the portion of the trace for Dec. 4, 1914, given in the illustration. The gusts on this day went up to eighty miles an hour.



Bidston. Portion of Trace of Milne-Shaw Seismograph on a Windy Day, December 4, 1914.

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The diurnal wandering at Bidston is small—much less conspicuous than the tidal or semi-diurnal. At Shide, as described more fully below, the semi-diurnal change is scarcely noticeable, while the diurnal is large and is related to temperature. In view of the investigation which follows, inquiry was made of Mr. Plummer as to what the temperature conditions were. He kindly installed a thermograph and sent the trace for two days, July 31 and August 1, 1915, which showed that the diurnal variation was on one day less than 1° F. and on the next about 1°.5, the external range on the first day being 8° and on the second 14°. If this may be interpreted to mean that the whole chamber is well shielded from the effects of external temperature, the absence of a marked diurnal effect is explained.

At Shide the Milne-Shaw and Milne-Burgess instruments are side by side on separate piers. Their booms are in opposite directions, and when the lines on one are crowded together those on the other are widely separated. There is no conspicuous tidal or semi-diurnal inequality, but there is a very large diurnal inequality, which, though far from constant in its action, usually crowds together the M.-B. trace and expands the M.-S., so that it is apt to run off the drum and be lost. It will be necessary to introduce some modification to meet this disability; and, in order to investigate its character and possibly to trace its cause, a number of corresponding traces in March 1915 were measured. The quantities tabulated in Table II. below are the measures corrected for the known travel of the drum, so as to represent displacements of the trace from its normal position. The reading at 11 A.M. is adopted as the zero, the paper usually being changed at about 10 A.M.

The numerical sums of the displacements are given at the feet of the columns, as a very rough indication of the relative sensitiveness of the instruments. The totals are 3,338 for the Milne-Shaw and 1,268 for the Milne-Burgess, which are approximately in the ratio of the magnifications, viz., 300 and 100. But we shall find that this ratio is not reproduced in the systematic wanderings.

TABLE II.

Displacements of Trace, in Units of 0·01 in.

Hour	Mar. 10		Mar. 16.		Mar. 17.		Mar. 29		Mar. 30.	
	M.-S.	M.-B.	M.-S	M.-B.	M.-S.	M.-B.	M.-S.	M.-B.	M.-S.	M.-B.
11	0	0	0	0	0	0	0	0	0	0
13	− 54	− 4	− 2	−15	−25	− 4	− 74	+ 1	− 55	− 2
15	−115	+ 3	−25	−32	−54	−14	−128	+13	− 80	− 1
17	−135	+16	−33	−39	−73	−21	−125	+22	−106	+ 2
19	−132	+30	−35	−38	−71	−18	− 96	+33	−113	+13
21	−114	+36	−25	−35	−53	− 9	− 44	+37	− 88	+21
23	−100	+43	−19	−31	−39	− 1	+ 14	+38	− 73	+26
1	− 92	+48	− 7	−27	−29	+ 1	+ 69	+33	− 47	+26
3	− 80	+55	+11	−26	− 9	0	+133	+23	+ 3	+18
5	− 79	+60	+29	−32	+13	− 7	+136	+16	+ 50	+ 7
7	− 53	+70	+33	−35	+27	−12	+103	+15	+ 44	+ 3
9	− 53	+79	+42	−39	+27	−24	+ 56	+13	− 3	− 1
Numl. Sum.	1007	444	261	349	420	111	978	244	672	120

We may now form the first harmonics for these sets of twelve readings, which are as follows :—

TABLE III.

—	Milne-Shaw.	Milne Burgess	$-R_B/R_S$	$\theta_B - \theta_S$
	h.	h.		h.
Mar. 10	$-44 \cos(\theta - 20{\cdot}4)$	$+30 \cos(\theta - 3{\cdot}8)$	+0·67	+ 7.4
Mar. 16	$-34 \cos(\theta - 18{\cdot}9)$	$+6 \cos(\theta - 10{\cdot}2)$	+0·18	(+15·3)
Mar. 17	$-47 \cos(\theta - 18{\cdot}9)$	$+6 \cos(\theta - 2{\cdot}5)$	+0·13	(+ 7·6)
Mar. 29	$-131 \cos(\theta - 16{\cdot}6)$	$+17 \cos(\theta - 22{\cdot}7)$	+0·13	+ 6·1
Mar. 30	$-76 \cos(\theta - 18{\cdot}5)$	$+14 \cos(\theta - 23{\cdot}7)$	+0·18	+ 5·2
Means	− 66	+ 15	+0·26	+ 6·2

The coefficient for the M.-S. machine is given with reversed sign, to make it directly comparable with M.-B. It will be seen that the magnitude of the displacement is much less for the M.-B. machine, though the ratios are not very consistent. A slight correction may be required for error in estimating the hourly travel. This error cannot be large, but there may be

(*a*) Error in estimating the pitch of the screw, which gives a spiral character to the trace. Thus for the M.-B. machine the screw was seen to have 17 turns in 4 inches. This estimate could not be so much as half-a-turn in error, and since a day uses 12 turns only, we may put the limit of error as less than 12 in our units of hundredths of an inch. Now if we form the first harmonic for the numbers

0 1 2 3 4 5 6 7 8 9 10 11

we find $-4 \sin\theta - 1 \cos\theta$. Applying this correction with the sign appropriate to making the ratios of M.-S. to M.-B. more accordant, and applying an equal correction to M.-S., guided by the same consideration, we get

TABLE IIIA.—*Being a possible correction to* TABLE III.

Milne-Shaw	Milne-Burgess	R_B/R_S	$\theta_B\ \theta_S$
$+43 \cos(\theta - 326°)$	$-26 \cos(\theta - 71°)$	0·60	105°
$+31 \cos(\theta - 292°)$	$-8 \cos(\theta - 198°)$	0·26	[266]
$+45 \cos(\theta - 304°)$	$-2 \cos(\theta - 18°)$	0·04	74
$+127 \cos(\theta - 264°)$	$-17 \cos(\theta - 288°)$	0·13	24
$+73 \cos(\theta - 293°)$	$-13 \cos(\theta - 350°)$	0·18	63

It will be seen that there is no great improvement in accordance of the ratios, while the phases are conspicuously more discordant.

(*b*) Errors may also arise from the drum not revolving in an exact hour or two hours. These again are not likely to be large, and their general effect would be as for case (*a*).

(*c*) Or there may be a real travel of the index during the day, owing to gradual change of temperature, for instance. If we treat this as a uniform change, its general form is still the same as case (*a*).

Coming to the phases, we see that there is a difference of about 90°, or 6 hours. The inference appears to be that the effect is not due to tilt of the ground, which should affect both instruments at about the same time, but an effect of temperature which acts promptly on the M.-S. instrument but much more slowly on the M.-B. The fact that

Mr. Shaw specially designed his instrument (with a thin metal cover, &c.) so that it might take up the temperature quickly supports this view. But the magnitude of the lag in M.-B., viz. 6 hours, is somewhat surprising, and to test its reality the numbers of Table II. were treated in a different way. Subtracting each constituent from that which follows it, we get the movements for each two hours, and can study the correspondence. It will be convenient to reverse M.-B. for this purpose.

TABLE IV.—*Two-hourly Movements of the Instruments.*

	Mar. 10 Reversed		Mar 16 Reversed		Mar 17 Reversed		Mar 29 Reversed		Mar. 30 Reversed	
	M.-S.	M. B.	M.-S.	M.-B.	M.-S.	M.-B.	M.-S.	M.-B.	M.-S.	M.-B.
h. h.										
11—13	−54	+ 4	− 2	+15	−25	+ 4	−74	− 1	−53	+ 2
13—15	−61	− 7	−23	+17	−29	+10	−54	−12	−25	+ 1
15—17	−20	−13	− 8	+ 7	−19	+ 7	+ 3	− 9	−26	− 3
17—19	+ 3	−14	− 2	− 1	+ 2	− 3	+29	−11	− 7	−11
19—21	+18	− 6	+10	− 3	+18	− 9	+52	− 4	+25	− 8
21—23	+14	− 7	+ 6	− 4	+14	− 8	+58	− 1	+15	− 5
23— 1	+ 8	− 5	+12	− 4	+10	− 2	+55	+ 5	+26	0
1— 3	+12	− 7	+18	− 1	+20	+ 1	+64	+10	+60	+ 8
3— 5	+ 1	− 5	+18	+ 6	+22	+ 7	+ 3	+ 7	+37	+11
5— 7	+26	−10	+ 4	+ 3	+14	+ 5	−33	+ 1	− 6	+ 4
7— 9	0	− 9	+ 9	+ 4	0	+12	−47	+ 2	−47	+ 4

Now, if we try the effect of associating the movement of M.-S.,
(*a*) with the contemporary movement of M.-B.,
(*b*) with the reading of M.-B. two hours later,
(*c*) with the reading of M.-B. four hours later,
and so on, we get, on grouping the results, the means shown in Table V.

TABLE V.—*Effect of Associating M.-S. with M.-B. of Various Times Later.*

	Corresponding Movement of M.-B after time						
M.-S.	h. 0	h. 2	h. 4	h. 6	h. 8	h. 10	6^h—M.S./8
−60	−3	−8	−10	−9	−5	−3	−1
−24	+3	−1	− 4	−6	−5	−2	−3
− 5	+2	+1	− 1	−2	0	+2	−1
+ 4	−8	−8	− 5	0	0	+4	−1
+12	−3	−1	− 1	0	+2	+3	−1
+22	−3	0	+ 3	+4	+5	+2	+1
+54	+5	+6	+ 5	+5	+3	+2	−2

Inspection of these figures indicates that the best correspondence is somewhere between 4 h. and 6 h. later, and nearer 6 h. than 4 h. But it was clearly desirable to have more light on the matter, and, as the next step, a thermograph was installed in the stable which forms the Observatory. It was not a very good thermograph, having been rather roughly treated in some mining experiments; but it gave a pretty fair indication of the temperature for several weeks. The readings May 4–10 and May 31–June 10 were selected for discussion. The traces were

measured with care and discussed at length, but a brief summary will suffice here:

May 4–10. The mean temperature first rose and then fell. But it will be convenient to consider first the mean diurnal inequality which came out in degrees Fahrenheit,

$$1°{\cdot}4 \cos (\theta - 20{\cdot}8^{h})$$

θ being expressed in hours. The late hour for the maximum, nearly 9 o'clock in the evening, raises hopes that we may be able to separate the effects of internal and external temperature. The first harmonics for the two machines were

	mm.	h.
Milne-Shaw	24·2 cos	$(\theta - 18{\cdot}0)$
Milne-Burgess	5 6 cos	$(\theta - 20{\cdot}3)$

The former measures and coefficients were inadvertently expressed in units of 0·01 in ; converted into mm., the former mean values are 16·8 and 3·8. These are smaller than the 24·2 and 5 6 now found, but the ratios, 4·4 and 4 3, are very nearly the same.

The phases, however, do not differ by nearly so large an amount. M.-B. follows M.-S. by 2·3 h. only instead of by 6 h. as found in Table V. It will be seen, moreover, that while the maximum of M. B. falls near that of the thermograph, M.-S. precedes the thermograph by a large interval—nearly 3 hours. Now, if the disturbance of the instruments is due to some temperature effect outside the Observatory—tilt in the valley, for instance—the time of maximum would be different from that of the thermograph. For instance, if it depended on the Sun's altitude, the maximum should fall at noon. If the effect is a composite one, the maximum would fall somewhere between noon and 20·8 h. (internal maximum), as it does in fact. We have thus a presumption of a composite character.

The presumption is strengthened by the magnitude of the coefficients ; —1° of temperature corresponds to 4·0 mm. for M.-B. and actually 17·7 mm. for M.-S. It seems unlikely that these movements, especially the latter, can be due directly to the 1° change in internal temperature It seems much more likely that they are due to the much larger external changes, of which the 1° internal change is only a fraction.

Further evidence in this direction is afforded by the changes of the mean from day to day, which can be formed when the diurnal change is eliminated. These were formed for every available day in the two periods May 4–10 and May 31–June 12, and it will suffice to give the mean results :

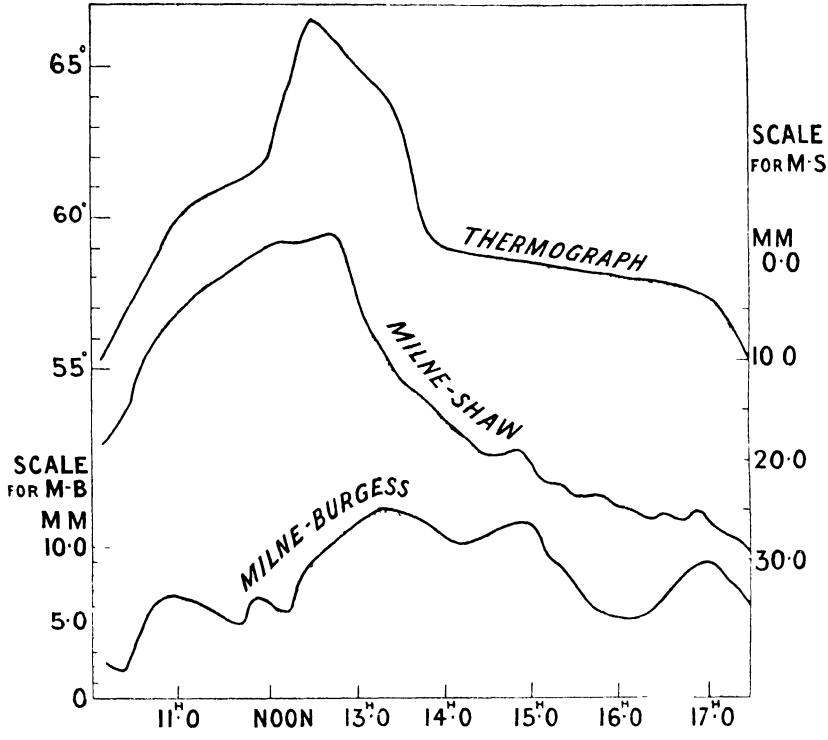
No. of Days in Group	Mean Change of Temperature	Observed Daily Travel of		Calculated	
		Milne-Shaw	Milne-Burgess	Milne-Shaw	Milne-Burgess
	°	mm.	mm.	mm.	mm.
4	+4·1	− 5·7	+5·6	−72·6	+16·4
3	+1·6	− 6·5	+3·2	−28·3	+ 6·4
5	0·0	−16·6	+0·7	0·0	0·0
4	−3·2	− 7·1	−8·6	+56·6	−12·8

Under the heading 'Calculated' are given the daily travels for the temperature change calculated with the coefficients 17·7 mm. and 4·0 mm. for 1° as found above from the diurnal inequalities. The M.-B. machine shows only about half the calculated travel; the M.-S. machine no sensible travel at all. It should be mentioned that the zero of the latter is adjusted every morning, but this does not affect the above figures, which are deduced (partly by estimation) from the undisturbed daily traces.

A test experiment was made on July 29 as follows:

At 10 a.m. a stove was lit in the Observatory in order to cause a rapid rise of temperature.

At 12.30 p.m. the stove was removed and a large block of ice was introduced in order to cause a sudden fall.



Temperature Experiment at Shide, July 29, 1915.

The readings of the thermograph and the corresponding wanderings of the two machines are shown in the diagram. It will be seen:—

(*a*) That neither machine responds to the rise of temperature in anything like the degree suggested by the diurnal coefficients. The total rise of temperature is over 10°, and we should expect deflections of 177 mm. and 40 mm. respectively; instead of which we get about 19 mm. and 11 mm.

(*b*) The Milne-Shaw begins to fall about 15 minutes after the thermograph, and falls pretty rapidly; the fall had not stopped when the observations were closured, and it is clear that the coefficient deduced from the fall would be greater than that found from the rise.

(*c*) The disturbance of the Milne-Burgess machine is much more complex. There are waves on the rise, and the main maximum which follows that of temperature by nearly an hour is followed by another 1½ hour later, and again another at 4½ hours after the temperature maximum. There may be others later still. A reasonable explanation is that the warmth reaches different parts of the instrument at different times, the separate parts producing separate maxima. This would fully account for the curious discrepancy between the former results, and the large range of values for the interval between M.-B. and M.-S. We have only to suppose that sometimes one part of the instrument is predominantly affected and sometimes another.

The main conclusion is that internal temperature can only be responsible for a part, and probably only a small part, of the diurnal deflections of the instruments. The main cause seems to be external, and is probably the daily opening and shutting of the valley to which Milne drew attention many years ago.

Before leaving these deflections, a word or two may be said as to the tidal effects, so conspicuous on the Milne-Shaw machine at Bidston, but almost hidden by the temperature effects at Shide. Some trouble was taken to disentangle them, and it was found that the lunar tide could be identified by means of the progressive phase. For the Milne-Burgess instrument the coefficient was about 1 mm.; but it is mixed up with temperature effects which may vary widely in character. The tidal coefficient for the Milne-Shaw instrument at Shide is not very much larger than 1 mm.—perhaps 2 mm. at most. But the material available at the time of the discussion was not large and further investigation is desirable.

Finally, some particulars may be given as to the deflections at other stations, where the simple Milne instruments are in use. The magnification being small, the disturbance of the trace by either temperature or tide is not noticeable to a casual glance; but if careful measures are made of the travel at every 2 hours (or 4 hours in some cases) throughout the day, the general nature of the movements can be detected. Such information may be of value in arranging for the setting up of instruments of higher magnification.

The diurnal changes were deduced from the means for all the days measured; as also the semi-diurnal changes.

As regards the lunar tide, the simplest way of detecting it is to form the differences between readings for 2 days separated by any convenient interval from 4 days to 11 days; for in 7½ days the lunar semi-diurnal tide reverses itself, maxima falling on the former minima. We thus get twice the effect by the subtraction. If the interval of 7 or 8 days is not available, the factor will not be so large as 2, but is easily calculated from the relation

$$\text{Cos}\ (\theta-\alpha)-\cos\ (\theta+\alpha) = 2\ \sin\ \alpha\ \sin\ \theta.$$

For 7½ days, $\alpha = 90°$; for 4 days, $\alpha = 4 \times 90°/7\frac{1}{2} = 48°$.

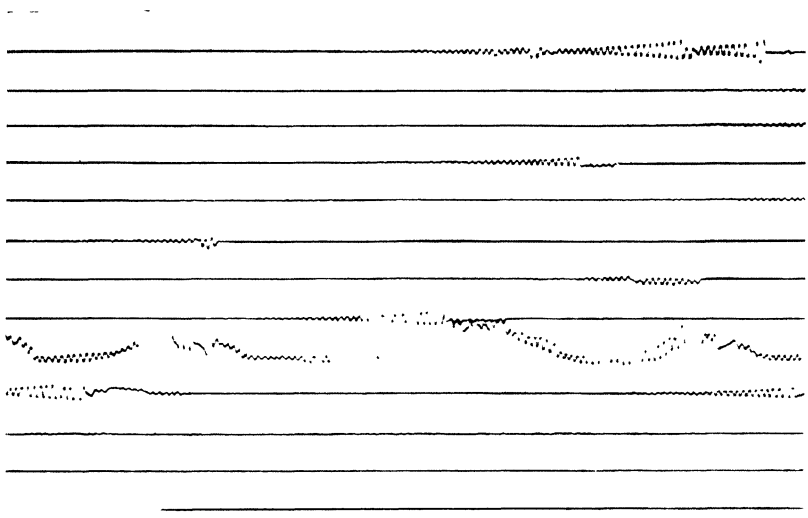
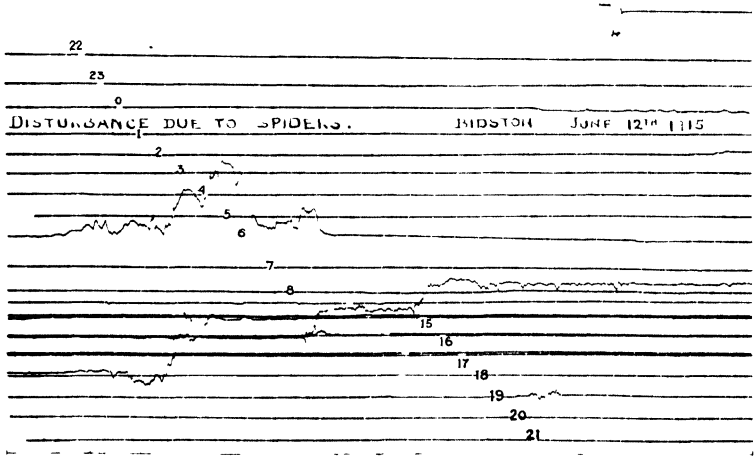


FIG. A.

St Helena, May 21 22, 1915

The effect of insects on a seismograph at St Helena. This continued for ten days

1915. [Opened June 11, 21, 23]



[Closed June 12, 21, 16.]

FIG. B.

The work of a spider on the seismograph at Bidston
He continued for eight days, until removed.

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Hence the factors are as below :—

Days	2	3	4	5	6	7	8	9	10
Factors	0·8	1·2	1·5	1 7	1 9	2 0	2·0	1·9	1·7

An example may make the method clearer. The actual readings of the Seychelles records are given in columns 2, 3, and 4 of Table VI. The unit is 0 01 in.

TABLE VI.

Hour	July 12	July 15	July 18	Differences 15–12	Differences 18–15	Diurnal Terms		Differences corrected for diurnal terms	
10	0	0	0	0	0	0	+3	0	−3
12	14	17	25	+ 3	+ 8	− 2	+4	+5	+4
14	33	31	42	− 2	+11	− 5	+6	+3	+5
16	65	50	59	−15	+ 9	−10	+7	−5	+2
18	96	78	80	−18	+ 2	−14	+8	−4	−6
20	120	100	105	−20	+ 5	−17	+9	−3	−4
22	139	122	130	−17	+ 8	− 18	+9	+1	−1
0	155	145	154	− 10	+ 9	− 16	+8	+6	+1
2	177	166	177	−11	+11	−13	+7	+2	+4
4	199	187	194	−12	+ 7	− 8	+6	−4	+1
6	228	221	220	− 7	− 1	− 3	+4	−4	−5
8	255	253	253	− 2	0	− 1	+3	−1	−3

In the next two columns the simple differences between July 12 and 15, and between July 15 and 18, are shown. These are clearly affected by diurnal terms, *i.e.*, the diurnal terms differ for different days, as we might expect. To bring out the lunar terms more clearly we remove the diurnal terms, including a suitable constant. The terms found (by harmonic analysis) are shown in the next two columns, and finally the corrected differences, which show the semi-diurnal terms clearly. Analysing these harmonically (as we could of course have done without removing the diurnal terms), we find :—

For July 15–July 12 :

$$0{\cdot}048 \text{ in. } \cos 2\,(\theta - 28^\circ) = 0{\cdot}048 \text{ in. } \cos 2\,(t - 11\,9) \text{ h.}$$

For July 18–July 15 :

$$0{\cdot}045 \cos 2\,(\theta - 52^\circ) = 0{\cdot}045 \cos 2\,(t - 13.5),$$

where θ is the hour angle measured from 10 h., or t is the time in hours measured from 0 h. The hour of maximum has thus advanced 1·6 h. in the 3 days. A purely lunar tide would advance 2·4 h. in 3 days. The discrepancy is partly accidental, partly due to a semi-diurnal temperature effect, which can only be detected or eliminated by a longer series of observations. But we can clearly separate the lunar effect by its advancing phase if we have a long enough series of days.

We proceed to give a few results for stations which had sent films to Shide for examination.

The measures were made in hundredths of an inch, and the travel of each trace is about 0·23 in. per 2 hours. The figures below, being deduced from only a few days' records, must not be taken too seriously,

but will serve to give an idea of the magnitude of the quantities involved.

Station	Dates of Traces Measured	Diurnal and Semi-diurnal changes						Coefficient of lunar tide
		in.		h.	in.		h.	in.
Ascension .	1911, Feb. 20–28	·014	cos $(\theta - 19{\cdot}5)$		+·005	cos 2 $(\theta - 0{\cdot}0)$		·004
Cocos .	1911, Sept. 5–22	·114	,,	20·0	+·026	,,	11·5	·028
Eskdalemuir, E.-W. .	1911, Feb. 1–22	·002	,,	22·5	+·021	,,	3·0	·000
Do., N.-S.	,,	·005	,,	22 0	+·008	,,	5·0	·000
Fernando Noronha	1913, Jan. 13–21	·081	,,	19 0	+·009	,,	6·0	·005
Helwan, E.-W. .	1911, Feb. 1–9	·001	,,	7·0	+·000	,,	—	·000
Do., N.-S	,,	·002	,,	12·0	+·000	,,	—	·000
Malta .	1911, July 1–9	·004	,,	18·0	+·000	,,	—	·000
Seychelles	1911, July 10–19	·035	,,	12·0	+·050	,,	4·0	·045
St. Helena	1915, Feb. 18–27	·016	,,	17·0	+·007	,,	2·5	·004
,,	1915, May 15–25	·007	,,	15·0	+·004	,,	3·5	·009

It will be seen that Eskdalemuir, Helwan, and Malta show no lunar tides; Seychelles and Cocos have large tides, as well as large diurnal effects.

It may be presumed that 0·001 in. = 0″·01 approximately, but in most cases no more precise scale value can be recovered from the records.

IX. *Insect Disturbances of Seismographs.*

An inquiry from St. Helena suggests that it may be useful to other observers to print a note on the disturbances caused by insects.

Mr. J. J. Shaw has kindly drawn up the following:

A difficulty which is frequently met with in practical seismology is to keep the seismograph free from the various insect interferences. An imprisoned moth or fly will often keep the boom in a state of unrest for several days at a time; but a much more serious nuisance is the ubiquitous spider; he not only makes havoc with the trace, but also ties up the boom, and very greatly destroys the sensitivity of the apparatus. It is useful to be able to decide from the trace whether the trouble is of the first or second order; because if of the second it is not sufficient to get rid of the spider, but the web must also be removed.

There is an advantage in making an artificial disturbance each day by standing for about 15 seconds on a selected spot near the side of the masonry column; a suitable time is just before changing the film, as the boom is then at rest. This will give a standard deflection which can be compared day by day whereby any loss in efficiency is quickly detected. The decrement curve at the commencement of the film is also useful in identifying the cause of these troubles. In instances of the first type the prisoner periodically sets the boom in motion, and occasionally leaves it to come to rest, when the trace will be seen to continue in alignment with its previous position. Confirmation may be looked for in the unimpaired efficiency indicated in the decrement curve. If, however, the disturbances produce permanent displacements in the trace they are probably caused by a spider, or perhaps a moth, whose

wings have been singed in the lamp, and which has fallen down the light aperture and become wedged between the slit plate and the floating vane on the boom. In either case the decrement curve and standard deflection will show considerable deterioration.

A piece of glass over the light aperture is a partial remedy; but more effectual is the addition of about 2 lb. of naphthalene ($C_{10}H_8$) well distributed throughout the cases.

Herewith are given illustrations of first-order trouble from St. Helena and spider trouble from Bidston. The Bidston apparatus is a fully damped Milne-Shaw type and has no decrement curve, but the standard deflection fell from 27 mm. to 9 mm. as a result of the webbing of this spider.

X. *The Identification of* S: *Suggestion of a New Phenomenon* Y.

As shown in the last Report, there are accidental deviations of observation of S from the times assigned by the tables. The mean of the errors discussed is ($\pm$0.73 minutes or) $\pm$44 sec. for S, and ($\pm$0.31 minutes or) $\pm$19 sec. for P. This is the more remarkable since the amplitude of S is usually much greater than that of P, so that there ought to be less uncertainty in reading. The suspicion is aroused that there is some other phenomenon liable to be mistaken for S; and that many of the errors are due to these mistakes.

A suggestion of this kind is put forward by Dr. G. W. Walker in his 'Modern Seismology,' but is apparently vitiated by an oversight. On p. 41, after considering the first reflected wave PR_1, he next considers a wave which travels as P to the point of reflection and as S subsequently; he points out that there is a lower limit to the possibility of such a wave which he determines as $\Delta=110°$ or 12,000 km.; and he proceeds:

'Now, it has been observed that special difficulty attaches to the identification of S just when Δ is about 12,000 km. Thus with an earthquake in the northern Philippines, which are about 11,000 km. from this country, S usually comes out very clearly, while in the case of an earthquake in the Caroline Islands, about 12,000 km. from us, S is most indistinct, and the tendency is to put it rather late. The result we have obtained throws some light on the matter.'

The oversight which vitiates this explanation is that Mr. Walker is dealing at the moment with the hypothesis of a homogeneous earth, which he soon shows to be quite untenable. His figures are those for a homogeneous earth, and are quite inapplicable to the actual earth. The lower limit he mentions does indeed exist, but instead of being at $\Delta=110°$ it is about $\Delta=35°$. It is readily found numerically by using the existing tables printed on the last page of the Shide bulletins for 1914. Thus when $\Delta=40°$ the times given for a wave to travel

		s.	s.	s.
as P for 1°	and S for 39°	= 15	+832	=847
P for 2	and S for 38	= 31	+818	=849
P for 3	and S for 37	= 47	+804	=851
P for 4	and S for 36	= 62	+790	=852
P for 5	and S for 35	= 77	+775	=852
P for 6	and S for 34	= 92	+760	=852
P for 7	and S for 33	=106	+744	=850
P for 8	and S for 32	=121	+728	=849
P for 9	and S for 31	=136	+711	=847
	&c.		&c.	

The sum of the times increases to a maximum of 852 sec., where there is an accumulation which marks the trace (P_1S_1) and then diminishes again. Since the time for S to travel 40° is by the same tables 847 sec., this P_1S_1 is later than S; and it is easily found to be always later. For instance, at

		s	s.
$\Delta=90°$	we have	$S=1454$	$P_1S_1=1507$
$\Delta=100$	,,	$S=1556$	$P_1S_1=1625$
$\Delta=110$	,,	$S=1648$	$P_1S_1=1738$

But in the above calculation for $\Delta=40°$ the distance travelled as P is only a few degrees; and as we diminish the value of Δ this distance contracts to zero, marking the limit determined by Mr. Walker in the simple case of a homogeneous earth.

The fact that P_1S_1 is always later than S is an additional reason why it cannot explain the mistakes in identifying S, which require a phenomenon sometimes preceding S, as will be seen from the examples quoted below. But there is scarcely need of an actual example; on general principles it is pretty clear that something preceding S is more productive of mistakes than something which follows; for there is a strong tendency to read the earliest movement in the suitable neighbourhood.

Now, if the phenomenon is to precede S, it seems clear that it cannot travel partly as P and partly as S, since even P_1S_1 is later than S. We cannot assign a smaller share to S than is represented by P_1S_1, except no share at all. We are thrown back on P.

A single reflection of P is well known as PR_1, and there is no difficulty in considering two, three, or more reflections of P. But when the appropriate neighbourhoods in the trace are examined, there seem to be no conspicuous indications there; certainly nothing likely to be mistaken for S.

The suggestion now put forward is that of a *large number of reflections of* P. When the number is large, the time of arrival tends to be independent of the precise number, since the times near the origin, whether for P or S, are sensibly proportional to the arcs. The printed tables give an initial velocity to P of about 1° per 15·5 s. The facts collated below suggest that this should be altered to 1° per 14·9 s. and this will be adopted for use provisionally. No large departure from the printed tables is involved—the time at 4·0° would be 59 6 s. instead of 62 s. as printed; but the times will be assumed for a moment to be accurately proportional to the arcs, at this rate.

On this supposition it is clear that a total arc of 60° is described in the same time by

			s.	s.
15	reflections of	4° each	$=15\times59{\cdot}6$	$=894$
30	,,	,, 2° ,,	$=30\times29{\cdot}8$	$=894$
60	,,	,, 1° ,,	$=60\times14{\cdot}9$	$=894$

And indeed that any number of reflections greater than 15 have the same total time of travel according to the tables. The simultaneity is only limited by the accuracy of our assumption that the time near the origin is directly proportional to the arc.

There is a difficulty attending this supposition of a theoretical kind. It is remarked by Mr. G. W. Walker on p. 45 of his 'Modern Seismology' that 'it is impossible to propagate along a plane boundary . . . longitudinal waves with displacement parallel to the surface.' Now, when

the P waves are many times reflected they must travel so close to the surface as to approximate to this impossible type. On the other hand, C. G. Knott ('Physics of Earthquake Phenomena,' chap. x.) gives, from theory, a total reflection of longitudinal waves at grazing incidence. The theoretical difficulty may disappear on scrutiny; if not, some other explanation must, of course, be found. But that now offered seems to fit the facts mentioned below, and is therefore put forward for consideration. It amounts to suggesting waves (Y) travelling close to the spherical surface with practically the initial velocity of P, which we take as 14·9 s. per degree. The times would thus compare with those of S as below:

$\Delta=$	60°	70°	80°	90°	100°	110°	120°
	s.	s.	s	s	s	s.	s.
Y=	894	1043	1192	1341	1490	1639	1788
S=	1103	1226	1343	1454	1556	1648	1729
Y−S=	−209	−183	−151	−113	−66	−9	+59

Mr. J. J. Shaw suggested the name 'polychord' for the phenomenon considered; and the letter Y from this term may be used to designate it. It will be seen that Y crosses S near $\Delta=110°$. But in the last Report certain corrections were suggested to the printed tables. It is not yet advisable to alter the figures used, as discussion is proceeding; but we may indicate in brackets the result of the corrections suggested, which are as below:

$\Delta=$	15°	25°	35°	45°	55°	65°	75°	85°	95°	105°
	s	s.	s.	s.	s.	s	s.	s	s	s
Correction P=	0	0	0	0	0	−1	−3	−8	−15	−24
Correction S=	+5	0	−4	−8	−11	−14	−17	−24	−35	−50

The comparison of Y with S would, with these corrections for S, stand as follows:

$\Delta=$	60°	70°	80°	90°	100°	110°
	s	s.	s	s.	s.	s
Y=	894	1043	1192	1341	1490	1639
(S)=	1090	1210	1323	1424	1514	1588
Y−(S)=	(−196)	(−167)	(−131)	(−83)	(−24)	(+51)

The point of crossing is thus shifted about 8° nearer the epicentre.

The plan of giving corrected figures in brackets will be followed below. The example which first suggested this hypothesis was the Eskdalemuir trace for the earthquake of November 24, 1914, to which attention was drawn by Mr. J. J. Shaw. The lettering on the rough trace shown in the illustration is his. See also Milne-Shaw record Plate II. At the time of examination of this trace no other material was available, and a brief summary may first be given of the argument as it then stood.

It is natural to identify α with P and γ with S. The distance of the epicentre corresponding to

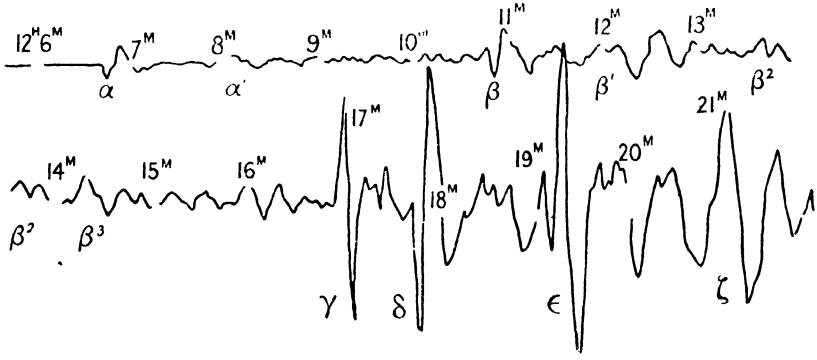
$$S-P=12\text{ h. }16\text{ m. }55\text{ s.}-12\text{ h. }6\text{ m. }43\text{ s.}=612\text{ s.}$$

would then be $\Delta=81{\cdot}3°$ (84·1 corrected tables). The time for PR_1 would then be 12 h. 10 m. 16 s. (12 h. 10 m. 30 s.). But PR_1 can almost certainly be identified with β at 12 h. 10 m. 54 s.*—much later than either the uncorrected or corrected time. Similarly, the time for SR_1 does not fit the trace at all.

If, however, we identify S with δ at 12 h. 17 m. 45 s. we then have

* This is the reading published by Eskdalemuir.

S—P=662 s. and Δ=90·8° (94·8°). The time for PR_1 would then be 12 h. 10 m. 35 s. (12 h. 10 m. 56 s). For SR_1 we should get 12 h. 24 m. 31 s.



Eskdalemuir (Galitzin) N.S. Component, November 24, 1914.

and there is a notable disturbance on the trace here (though it has not been considered necessary to reproduce that part of it in the diagram).

This argument has been much strengthened since the records of other stations became available. These were collated by Mr. Burgess in the ordinary course of the work at Shide in July 1915 without any knowledge of the suggestion here made. The epicentre selected by him is 21·5° N. 141° E. distant 97·3° from Eskdalemuir; and the MS. sheet prepared for the Shide Bulletin with this epicentre shows residuals in S of over 100 s. not only for Eskdalemuir and Dyce (Aberdeen), but for Padova, Paris, and other stations. It would appear that γ has been taken instead of δ at such stations, for the above epicentre, though possibly a few degrees in error owing to the conflicting information, suits the near stations (Zi-ka-wei, Batavia, and the Japanese stations), as well as Pulkovo, too well to be so far wrong as must be the case if γ were S.

But if δ is S, what is γ? Taking Δ=(94·8°) as above, the time for the polychord is 94·8×14 9 seconds=1413 s., following P by (606 s.), and thus affecting the trace at (12 h. 16 m. 49 s). The Eskdalemuir reading for S (*i.e.*, for γ) is 12 h. 16 m. 56 s.

The full details for this earthquake, which is not at present fully discussed, will be printed in the Shide Bulletin; but the following figures will show approximately the nature of the results:

Epicentre 24° N., 141° E. *Time*, 1914, Nov. 24, 11 h. 53 m. 15 s.

Station.	Inst.	Δ	P	O−C	S	O−C	O−C for Y instead of S.
		°	h. m. s.	s.	h. m. s.	s.	s.
Zi-ka-wei . .	W	18·7	11 58 2	(+22)	12 1 36	(+26)	—
Batavia . .	W	41·9	12 1 30	(+ 5)	12 7 48	(+ 5)	—
Pulkovo . .	G	79·2	12 5 28	(+ 4)	12 15 17	(+ 8)	+142)
Dyce (Aberd.) .	Ma	93·2	12 6 24	(−10)	12 16 31	(−58)	(+ 8)
Eskdalemuir .	G	95·0	12 6 43	0	12 16 56	(−50)	(+ 6)
Padova . .	V	96·7	12 6 51	0	12 17 5	(−55)	(− 9)
Bidston . .	MS	96·7	12 6 52	+ 1	12 17 6	(−54)	(− 10)
Paris . . .	G	98·3	12 6 59	0	12 17 14	(−60)	(− 15)

Another example is afforded by the earthquake of June 25, 1914, details of which have already been published in the Shide Bulletin for June. Let us first take the following residuals:

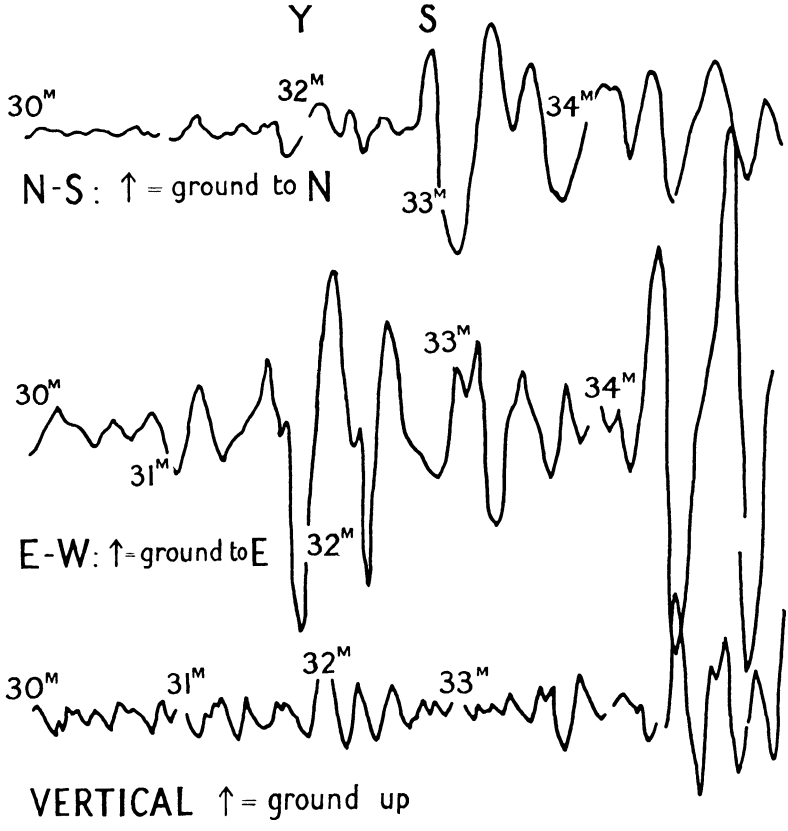
	P			O−C	S			O−C
	h.	m.	s	s	h.	m.	s.	s.
Eskdalemuir .	19	21	15	+18	19	32	55	+10
West Bromwich .	19	21	17	+21	19	31	45	−58

It is clear that if Eskdalemuir is even approximately correct, the S for West Bromwich is sensibly in error. Now, the West Bromwich trace shows, following the printed S at 19 31 45, another disturbance about 45 s. later, say at 19 32 30, which is probably the true S. The printed Δ for West Bromwich is 100·3°, for which Y−(S) would be only −22 s. according to the figures above given But the position of the epicentre is subject to revision. The printed distance 100 3° would give S−P=11 m 45 s. (11 m 22 s. corrected), whereas the West Bromwich trace suggests the smaller value 11 m. 13 s., corresponding to Δ=(98·3°) say: for which Y−(S)=(−35 s.).

For this earthquake the S residuals for Florence, Aachen, Barcelona, Dyce, Honolulu, &c., all accord with a mistake of Y for S. On noticing the above discrepancy between Eskdalemuir and West Bromwich, inquiry was made of Eskdalemuir, and on April 23 Mr. Richardson kindly replied 'the time stated (for S) in our tabulation was the correct one for a certain disturbance on N.-S. But on unravelling the E.-W. trace it is seen to contain a disturbance about a minute earlier. Photo. prints are being sent to you herewith.' A rough tracing of the three records is given in the illustration. It will be seen that Y is small on the N.-S component; large on the E.-W. component, and quite noticeable (though S is absent entirely) on the vertical component. These facts seem to accord with a wave of P character, for the epicentre is nearly due east of Eskdalemuir, the azimuth (from the north point) being 82·6 if we accept the epicentre of the June Bulletin (4·5° S., 99° E). A thrust from this direction would be 7·7 times as much to the W. as to the S. Now measurements of the traces give for the first three south movements in millimetres +8·5, −12·0, +9·0; and for the corresponding west movements, +57, −72·5, +65. Dividing the latter by 7·7 we get +7·4, −9·4, +8·4, which are all a little smaller than the former. The ratio (57+72·5+65)/(8·5+12·0+9·0)=6·6 in fact, giving an azimuth for the epicentre of 81·5° instead of 82·6°. The epicentre determined at Eskdalemuir (1° S., 102° E.) gives azimuth 78°, so that the correspondence is thus well within the limits of accidental errors of various kinds. It would be interesting to check this ratio from the S movements, which ought to be, and are, large in the upper trace where Y is small, and small in the lower trace. But, unfortunately, they are masked in the lower trace by the end of the Y movements; at any rate this is a reasonable interpretation of the trace. In fact, the epicentre is in a particularly favourable azimuth for separating Y from S, and the sentence above quoted from Mr. Richardson's letter takes on a new significance when this is realised. If the azimuth had been nearer 45° or one of the other octants, Y and S might have been mixed up in both traces, and the beginning of Y would probably have been read as the beginning of S. The possible effect of this confusion

on the construction of the tables in use requires very careful consideration, and is an additional reason for deferring the proposal of definitive corrections. Indeed, it seems probable that these cannot be made without a somewhat extensive study of the traces themselves in addition to the collation of the times published by the various observatories.

There is one further point to be considered—the depth of the focus below the surface. If this be at E (see page 73) and CEc be the chord perpendicular to the radius OEK, then all other chords through E are



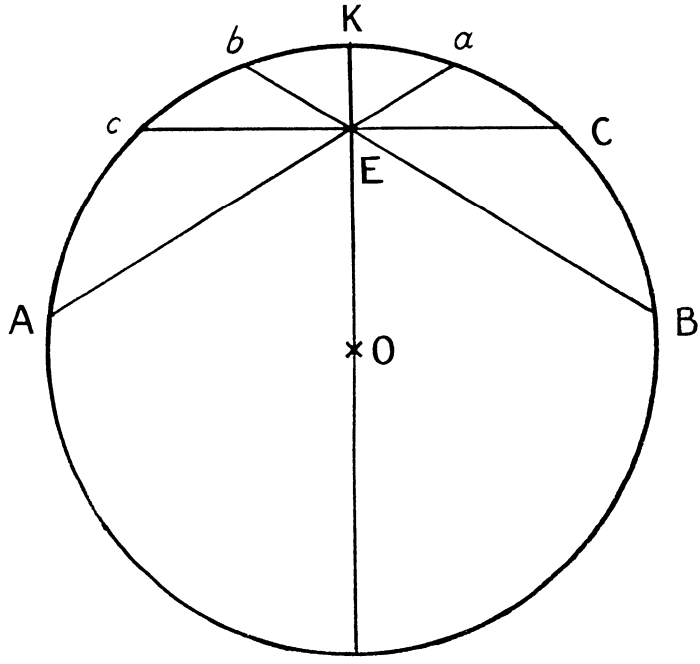
Eskdalemuir, June 25, 1914.

longer than *c*C, and occur in pairs such as *a*EA and *b*EB. Waves travelling from E by either the path E*a* or EB would on reflection travel by consecutive steps all equal to *a*A or *b*B. Hence, *c*C represents the minimum step for waves emanating from E, and is larger as E falls further below the surface. It seems possible that if E is too near the surface (or perhaps above it) these nearly tangential reflected waves cannot occur, and we get no 'polychord' or Y phenomenon. This may explain why it has only occasionally attracted notice. Both the epicentres

above considered are out at sea. It will be interesting to note whether there is a difference between sea and land epicentres in the matter of Y; but this examination has not yet been made.

In this connection such earthquakes as that of July 4, 1914, may be significant. It is noted in the Shide Bulletin that

> a shock at 17 h. 46 m. 30 s. was followed some 100 seconds later by another at another epicentre (12° away); but the curious thing is that the nearer stations (Manila, Batavia, &c.) have recorded the second quake and not the first



The suggestion now offered is that the first focus was on or even above the surface, that the path of waves from it has a limiting (minimum) depth, and therefore a limiting (minimum) radius for affected stations, while the second focus was below the surface and was not restricted. If such limits do exist, their application to the possible formation of Y is tolerably obvious.

XI. *Correction of Tables deferred.*

Provisional corrections to the tables for P and S were given at the end of the last Report and are repeated above (p. 67). But the tables printed on the last page of the Shide Bulletins will be used for the present, until a fuller discussion has been made. Meanwhile, the above provisional corrections are made use of in determining epicentres, and they

can be used in studying the residuals. Thus, in the quake of July 4, 1914, the following residuals:

Station.	Machine.	Δ	(O−C) for P.	(O−C) for S.
Graz	W	98·8°	−6 s.	−16 s.
Zagreb. . . .	W	99·4°	−8 s.	−25 s.

are to be considered subject to corrections +19 s. and +41 s. approximately (change sign of tabulated corrections, which apply to the C in O−C). Similarly, those for Pulkovo −9 s. and −28 s. are subject to corrections (Δ=85·2°) + 8 s. and +24 s.

XII. *Shide Bulletins.*

From January 1914 the Shide Bulletins have been arranged with a view to the ultimate discussion of the best material. Earthquakes not observed at many stations appear only on the 'chart' as in the previous year's records; but for the better observed earthquakes, whereas for 1913 the recorded times were printed without discussion, from January 1914 they have been compared with calculated times. Epicentres were at first adopted from the Pulkovo determination simply; but as it was found that these were often sensibly in error (owing partly to the errors of the tables) fresh determinations of epicentre have been recently made at Shide.

The preparation of these bulletins has very considerably increased the work at Shide; but it is hoped that the extra work is profitable.

XIII. *New Method of Computation.*

Some of the labour has been abridged by the adoption of a new method for calculating the distance of a station from an epicentre. If (l, d) be the longitude and latitude of a station, (L, D) those of the epicentre, and if we put

$$a = \cos l \cos d \qquad b = \sin l \cos d \qquad c = \sin d$$
$$A = \cos L \cos D \qquad B = \sin L \cos D \qquad C = \sin D$$

then the formula used is

$$2 \text{ versin } \Delta = (a-A)^2+(b-B)^2+(c-C)^2.$$

The quantities a, b, c are constants for the stations and have been tabulated. A, B, C are readily formed for each epicentre. A table of squares to 4 figures is amply sufficient to give the $(a-A)^2$, &c., and a table has been formed of 2 versin Δ which saves even the division by 2. A fuller description of the process and the table for 2 versin Δ will be found in 'Mon. Not. R A.S.,' lxxv. p. 530

XIV. *Standardizing a Milne-Shaw Seismograph*

[This section is kindly contributed by the Superintendent of the Meteorological Office. It was written by Mr. L. F. Richardson, of Eskdalemuir, and was completed on September 3.]

This instrument (No. 3) was set up at Eskdalemuir, in July 1915, by Mr. J. J. Shaw. A description of it will be found in Section VI. of this Report.

The pivoted mirror and the link which connects it to the boom are both very light, and in the first instance the instrument has been regarded as a simple boom connected to a massless multiplying device. The theory of such a boom is set out in most text-books on seismology.

The magnification of impulsive horizontal displacements of the ground may be found in two ways :—

(1) The easier way is to obtain it from the period of undamped oscillation, together with the sensitivity to static tilt ('Modern Seismology,' by G. W. Walker, page 23).

According to Mr. Shaw's advice, when observing the period, the damping magnets were entirely removed, not merely tied up to the pillar, lest their weight should bend the latter. The period came to 9·88 secs. for small swings. 10·08 for large ones, and 9 9 has been taken in the subsequent calculation.

The arrangements provided for determining tilt are very convenient. The pitch of the tilting screw, the distances between the feet and the lengths of the path of light, were all measured, and the scale of tilt thus verified to $\frac{1}{2}$ per cent. The sensitivity to static tilt was found to be $6{\cdot}8_8$ mm. on the paper per 10^{-6} radian. Now the magnification for sudden lateral displacements is

$$\frac{\text{(cms. on paper)} \times 4\pi^2}{\text{(radians tilt)} \times g \times (\text{period})^2},$$ which comes to 282.

(2) As a check, the same magnification was calculated independently from the lengths of the levers and the radius of gyration of the boom about its pivot. In the sketch, BR is the boom pivoted at R. CB is a link, CD a lever pivoted at D, and D is also the mirror. P is the photographic paper.

Lengths of Levers.—The small length CD was measured by a travelling microscope. The distance from the mirror D to the photographic paper was diminished by $\frac{1}{3}$ of the thickness of the cylindrical lens. The length of the equivalent mechanical pointer was taken as $2\,\frac{(DP - \frac{1}{3}K)(BR)}{CD}$, and came to 30·0 metres. Here K is the thickness of the cylindrical lens.

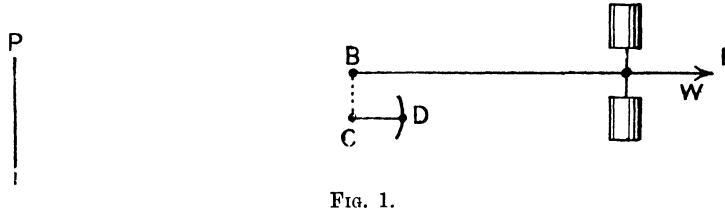


FIG. 1.

Radius of Gyration.—To find this, the moments of inertia about the pivot R of the several parts were measured separately, added up, and divided by the total mass.

The moment of inertia of the boom was found from the position of its centre of mass, together with its period of vibration, when hung up vertically by a short thread attached at W and set to oscillate about a horizontal axis through R.

The heavy dumb-bell shaped mass was at first pivoted upon the boom, as in some Milne instruments ; the intention being to diminish the moment of inertia. The gain in this respect is less than 20 per cent. of the whole moment of inertia of the moving system. On the other

hand, it was found that the freedom of the dumb-bell set up undamped oscillations of the light spot; so Mr. Shaw clipped the mass rigidly to the boom. The moment of inertia of the dumb-bell about its centre of mass was measured by hanging up the dumb-bell by a bifilar suspension and observing its time of oscillation. In this way the radius of gyration l of the whole moving system about the point R was found to be 11·66 cms. The magnification for impulses of lateral displacement is $\frac{L}{l} = \frac{3000}{11{\cdot}66} = 257$. There is an unexplained discrepancy of 10 per cent. between this figure and 282, which might be sought for in the neglected action of the multiplying lever. This was not quite perfectly balanced. In the tilting experiment it remains untilted.

In drawing fig. 2 the mean of 257 and 282 has been used.

Magnification for Long-continued Sinusoidal Waves of Lateral Displacement.—When the period is infinitely short, this is the same as the magnification for impulses. The diminution of the magnification with increasing period of the earth-wave is determined from the period of the pendulum and the degree of its damping, according to the well-known formula (Walker's 'Modern Seismology,' page 5). To obtain the damping, a piece of a soft iron nail was attached to the boom. A small solenoidal coil of wire was fixed on the pillar so that the iron was half inside the coil. By passing a momentary electric current through the coil the boom was set in motion. Care was taken that the applied force did not continue for more than a small fraction of the quarter-period of vibration. As the solenoid had no fixed iron core, there were no after-effects. As one has to measure the ratio of successive swings, this ratio

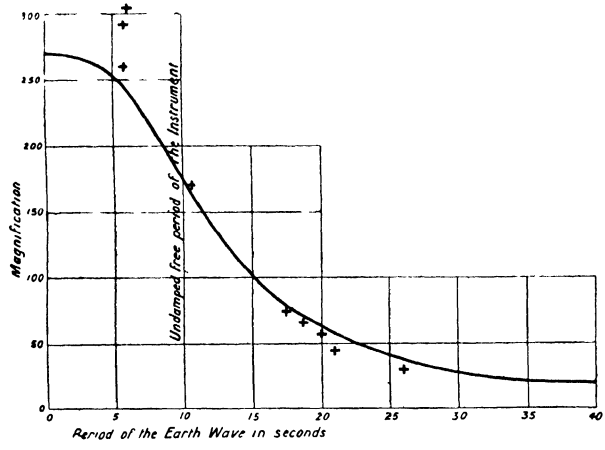


FIG. 2.

Milne-Shaw Seismograph, No. 3. July 26, 1915.
The full-line curve gives the magnification for long-continued sinusoidal waves of lateral displacement.
Undamped free period of pendulum 9·9 secs.
Damping ratio of successive swings on opposite sides of zero 45 : 1.
The crosses are from the Galitzin instrument.

must not be too large. The measurements were made on the photographic record, and gave 45 : 1 for the ratio of successive displacements on opposite sides of the zero. From these data the curve in fig. (2) was plotted.

Comparison of the Magnification with that of a Galitzin Instrument having Galvanometric Registration.—This was done by selecting a point of time at and near which the natural disturbance was of a regular sinusoidal character on the seismograms of both the Milne-Shaw and Galitzin instruments. The two instruments were in the same room (though on separate piers) and their booms were parallel to one another, so that we may assume that the ground motion was the same for both. The amplitude and period of the Galitzin chart were measured, and from these and from the known constants of the Galitzin instrument the amplitude of the ground motion was deduced. Dividing this quantity by the amplitude on the Milne-Shaw record we get the magnification of the latter instrument. The figures so obtained have been represented by the crosses in fig. 2. The agreement of the crosses, with the curve obtained by consideration of the Milne-Shaw instrument alone, is nearly as good as could be expected, considering the uncertainties involved in measuring the small amplitudes of 1 or 2 mm. on the Milne-Shaw record. The constants of the Galitzin instrument were obtained in May 1915 by the method of tapping the boom (Galitzin's 'Lectures,' ch. vii. § 3) and differ only slightly from those obtained in previous years.

Direction on the Paper.—The boom is suddenly pulled to the west. The light spot therefore moves as if the ground had been jerked to the east. This test is made on every sheet.

Lag of Maximum.—The usual theory of lag begins by assuming that the ground is in a regular and constant state of sinusoidal motion. Each wave is by hypothesis exactly like its neighbours, and therefore it is impossible to distinguish one wave from another, and the lag is indeterminate as to an arbitrary number of whole wave-lengths. This is the only arbitrariness. The theory usually ends, however, in a formula which gives the tangent of the angle of lag, and the angle is therefore unspecified as to a whole number of *half* wave-lengths. On going back and examining the sine and cosine of the angle of lag this uncertainty disappears, in so far as it concerns the phase relations of the quantities represented by the symbols in the theory. But there is still a practical uncertainty of half a wave-length until we have connected the symbols to our practice in reading records, by defining the relation of east and west ground-motion to up and down the record. The definition here adopted is that when all is at rest and the ground suddenly moves, then the initial displacement of the trace on the developed photographic record is conventionally said to be in the same direction as the initial motion of the ground. The actual test is made by pulling the boom in the opposite direction, as stated above.

Now the equation of motion of a 'critically aperiodic' boom is

$$\left(\frac{d}{dt} + n\right)^2 \theta = -\frac{\ddot{x}}{l}, \quad \ldots\ldots\ldots \quad (1)$$

where θ is the angle turned through by the boom.

Here x is the displacement of the ground.

n and l are positive constants.

For sudden motions we may neglect n in comparison with $\frac{d}{dt}$ and we have left

$$\dot{\theta} = -\ddot{x}/l.$$

So that the standard relation of signs is $+\theta$ with $-x$.

For very slow motions we may neglect $\frac{d}{dt}$ in comparison with n, and we have left

$$n^2\theta = -x/l.$$

Now let $-x = \sin pt$,

$$\text{then } \theta = -\ddot{x}/nl^2 = -\frac{p^2}{nl^2}\sin pt.$$

Thus θ lags *half a wave-length* behind $-x$. The sign of either side of equation (1) may be changed without affecting this result. Galitzin gives a numerical table for this lag ('Seismometrische Tabellen,' Tabelle VI.), as a function of the degree of damping and of the periods of the pendulum and ground. But as he gives the lag as zero for waves of very long period, instead of half-a-wave as found above, it is clear that he has adopted a different definition of the direction on the paper, and that his definition would give the reversed sign to sudden motions if it were applied to them,

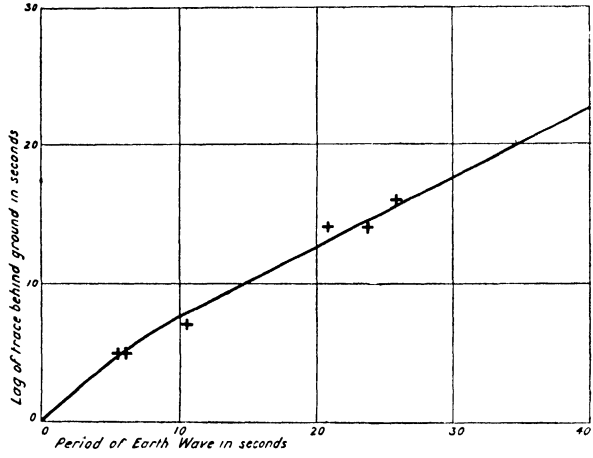


FIG. 3.

Lag of Milne-Shaw Seismograph, No. 3. July-August 1915.

which probably is not intended. In preparing fig. 3, the lags in Galitzin's Table VI. have therefore been increased by half the period of the earth-wave.

In order to make an observational comparison between the lag of the Milne-Shaw instrument and that of the Galitzin instrument with galvano-

metric registration, it was necessary to examine the theory of the latter, when the direction on the paper is defined by means of sudden motions from a state of rest. By analysis similar to that given above it may be shown that the numbers for the lag of the galvanometer behind the pendulum, given by Galitzin in his Table VII., are also based on a definition differing by half-a-period from that here taken. So that the sum of the lags given in Galitzin's Tables VI. and VII.—that is to say, the lag of the galvanometer behind the ground—is in agreement with the definition here taken. Of course, it is arbitrary as to a whole number of wave-lengths.

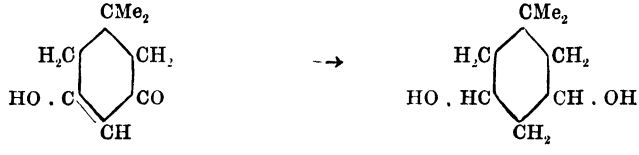
In fig. 3 the crosses indicate the lag found for the Milne-Shaw instrument, taking the lag calculated for the Galitzin instrument as correct.

The Study of Hydroaromatic Substances.—Report of the Committee, consisting of Professor W. H. PERKIN (*Chairman*), Professor A. W. CROSSLEY (*Secretary*), Dr. M. O. FORSTER, Dr. H. R. LE SUEUR, *and* Dr. A. MCKENZIE.

1. *Bromoxylenols obtained from dimethyldihydroresorcin.*[1] The transformation of certain hydroaromatic substances into bromoxylenols, alluded to in the last Report,[2] has now been completed.

2. *Derivatives of Isopropyldihydroresorcin.*[3] The preparation and properties of 1-isopropylcyclohexan-3-ol and 1-isopropylcyclohexan-3-one, briefly referred to in the last Report, have been described in detail.

3. *Dihydric Alcohols obtained by the reduction of substituted dihydroresorcins.*[4] It has been shown that 1:3-dibromo-derivatives of the saturated cyclohexane hydrocarbons may be used for the preparation of substituted cyclohexadienes.[5] It would appear that a more expeditious method of preparing these substances would be from the dihydric alcohols, which, on theoretical grounds, should be easily obtained by the direct reduction of the dihydroresorcins,

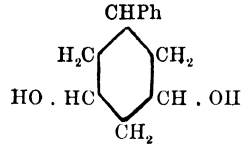


but though many attempts have at various times been made to bring about these reactions, in some cases resulting in the isolation of small quantities of the desired substances, it is only comparatively recently that conditions have been worked out for the preparation of the dihydric alcohols in quantity.

Knoevenagel[6] obtained small amounts of phenylcyclohexane-3:5-

[1] *J.C.S.*, 1914, **105**, 165.
[2] *Reports*, 1913, p. 135.
[3] *J.C.S.*, 1915, **107**, 171.
[4] *J.C.S.*, 1915, **107**, 602.
[5] *J.C.S.*, 1908, **93**, 629.
[6] *Annalen*, 1895, **289**, 167.

diol (I) by the reduction of phenyldihydroresorcin with sodium and alcohol, and the only other paper



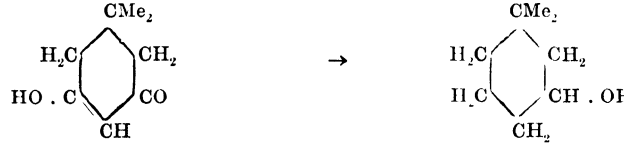
(I)

dealing with this subject is one by Zelinsky and Uspenski,[7] who also employed the same reducing-agent. Numerous experiments have confirmed the fact that sodium and alcohol give the best results, and the yields are highest when the reaction is carried out energetically by heating in an oil bath to 110°, as stated by Zelinsky and Uspenski.

The amounts of the dihydric alcohols produced vary considerably with different dihydroresorcins, as is seen from the following table:—

	Yield per Cent
Methyldihydroresorcin	43
Dimethyldihydroresorcin	66–68
Trimethyldihydroresorcin	20
Isopropyldihydroresorcin	40
Phenyldihydroresorcin	47–50

This is partly due to the nature of the dihydroresorcins themselves, but also to the fact that the reactions are somewhat complicated, and it is interesting to note that, in all cases, small quantities of the corresponding monohydric alcohols are formed. For example, 1:1-dimethylcyclohexan-3-ol (II) from dimethyldihydroresorcin (III).



(III) (II)

Further, owing to the unsymmetric structure of all the molecules except that of dimethyldihydroresorcin, isomeric forms of the diols are produced, the separation of which is always tedious and sometimes has been found impracticable.

The dihydric alcohols are crystalline compounds, neutral to litmus, readily forming dibenzoyl derivatives and not absorbing bromine in chloroform solution. In many properties they strongly resemble glycols, as they possess a sweet taste, are easily soluble in water, and not readily soluble in ether.

4. 1:1-*Dimethylcyclohexane.* In a paper entitled *gem*-dimethylhexamethylene,[8] Zelinsky and Lepeschkin describe the preparation of 1:1-dimethylcyclohexane from 1:1-dimethylcyclohexan-3-one, which was obtained from acetylmethylheptenone.[9] These authors conclude that

[7] *Ber.*, 1913, **46**, 1436. [8] *Journ. Russ. Phys. Chem. Soc.*, 1913, **45**, 613.
[9] *Bull. Soc. Chim.*, 1899 (3), **21**, 546.

their hydrocarbon possesses physical properties identical with those of 1 : 1-dimethylcyclohexane prepared from dimethyldihydroresorcin,[10] but state that it gives on treatment with bromine in presence of aluminium bromide, tetrabromo-p-xylene, melting at 256°. Recent work has shown that 1 : 1-dimethylcyclohexane may be prepared from acetylmethylheptenone as a starting-point. This hydrocarbon, on treatment with bromine in presence of aluminium bromide, does not give tetrabromo-p-xylene, as stated by Zelinsky and Lepeschkin. Further, 1 : 1-dimethylcyclohexane on treatment with a mixture of nitric and sulphuric acids gives the two isomeric trinitro-o-xylenes, melting at 72° and 115° respectively, which proves that, as in so many instances already recorded, the methyl group has again wandered into an ortho and not a para position.

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, Sir J. J. DOBBIE, *and* Dr. M. O. FORSTER. (*Drawn up by the Secretary.*)

α′-Chlorocamphor.[1]

DURING the past year the principle of dynamic isomerism has been applied in preparing, in a pure state and in considerable quantity, the first member of a hitherto unisolated series of halogen derivatives o camphor. α-chlorocamphor, as Kipping found in 1905, becomes isodynamic with the stereoisomeric α′-chlorocamphor when alkali is present; when the alkali is removed the isomerism again becomes static, and the isomerides can be separated by ordinary methods of fractionation.

α′-chlorocamphor presents several points of special interest :—

First. It lies on the borderland between the more labile and the wholly stable forms of isomerism; if proper precautions are taken, the α′- compound can be kept an indefinite time, but if carelessly handled (*e.g.*, if crystallised from a medium containing traces of alkali) it may at any time revert to the less soluble and therefore more stable α- compound.

Second. When brominated it gives a mixture of stereoisomeric αα′-bromochlorocamphors in exactly the same proportions as when α-chlorocamphor is brominated, *i.e.*, the position taken up by the bromine is not affected in the least by the position which the chlorine atom occupies. This remarkable result is in agreement with Lapworth's view that in the bromination of ketones it is an enolic isomeride that is first attacked; more generally we may conclude that at some stage in the bromination α and α′-chlorocamphor give rise to some identical intermediate product.

Third. In complete contrast with their behaviour on bromination,

[10] *J.C.S.*, 1905, **87**, 1487.

[1] The experiments on α′-chlorocamphor have been made by Mr. Victor Steele, and are described in detail in a joint paper recently communicated to the Chemical Society.

α and α′-chlorocamphor give on nitration the pure chloronitrocamphor directly derived from the chlorocamphor employed; thus α-chlorocamphor gives α-chloro-α′-nitrocamphor, whilst α′-chlorocamphor gives an excellent yield of α′-chloro-α-nitrocamphor. The latter compound had already been fractionated out in small quantities from the mixture of stereoisomers which is obtained by chlorinating α′-nitrocamphor; but, as α′-chlorocamphor can be prepared and nitrated on a large scale, the nitro- derivative will now be available in much larger quantities. This fact may be of considerable importance, since the reduction of the chloronitro- compound may give the long-sought but still unknown α-nitrocamphor.

Fourth. α′-chlorocamphor appears to lose hydrogen chloride much more readily than the α- compound. If this decomposition should involve the removal of a hydrogen atom from the nucleus, an entirely new chapter in the chemistry of camphor may be begun.

In view of the large amount of work that is waiting to be done in this and in other directions, the Committee asks to be reappointed with a grant sufficient to defray the cost of extending the experiments to the β and π derivatives of camphor.

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, *and* Dr. J. T. HEWITT.

VERY little work has been possible in the circumstances throughout the year owing to preoccupation with other more pressing duties, and to the departure for military and other like services of the senior students, who would have carried out the experimental part of the investigation. The work, of which a short report follows, is therefore to be regarded as purely of a preliminary character.

The Relation of the Velocity of Chlorination of Aromatic Compounds to Constitution.

(With D. C. JONES.)

The measurement of the velocity of chlorination of a number of acylanilides, acylchloroanilides, and acyltoluidides and acylxylidides [1] showed that the velocity of the reaction was highly sensitive to:

(a) the nature of the acyl group;
(b) the nature of a substituting group, chlorine or alkyl, present in the substance;
(c) the position of the substituting group.

It has been our intention to extend these observations by studying the influence of substituents other than chlorine and alkyl, for example, bromine and the nitro- group; and to compare with the amino- and the acylamino- group, -NHAc, such other ortho-para- directing groups as hydroxyl, alkoxy-, and alkyl.

[1] Orton and King, Reports, 1911; *Trans. Chem. Soc.* 1911, 99, 1377.

It is hoped that by study of a number of substances of suitable constitution the relative activities of directing groups in chlorination might be expressed as numerical values. The investigation is not of the simplest, for direct measurement in the case of an aniline or phenol, and so forth, is rarely possible owing to the very great speed of entrance of the first and often further chlorine atoms. Derivatives in which other groups, such as the nitro- group, are present, must be used in order to obtain a measurable rate of chlorination. Holleman has, in recent years, made attempts to compare the activities of directing groups by nitrating compounds which contain two directing groups and then estimating the proportion of the different nitro- derivatives in the product. By this means he has arrived at certain relations, which can be expressed numerically. Our method has the advantage of being simpler in manipulation, and should at least yield more direct values.

Experimental Method.—The method of experiment [2] has now been thoroughly tested and has not been modified in these later experiments.

(1) *The Effect of the Nitro- Group.*—A nitro- group in the para position with respect to the directing group greatly inhibits chlorination; the effect is still more marked when the nitro- group is in the ortho- position. In the case of phenols the nitro- group appears to have some definite specific action; phenols are chlorinated with very great speed, but chlorination of *o*- and *p*-nitrophenols, especially of the former, is very slow. *o*- and *p*-nitroaniline, on the other hand, are chlorinated at speeds which differ little from those observed with the corresponding monochloroanilines Although the amino- group is a far more active directing group in chlorination than the hydroxy- group, this result would indicate that a free hydroxy- group is not present in *o*- and *p*-nitrophenol.

(2) *Alkoxy- Groups as Directing Groups in Chlorination.*—Measurements have shown that the methoxy- and ethoxy- groups have a quite unexpectedly high activity in chlorination. The entrance of the first chlorine atom into anisole, $C_6H_5.OCH_3$, and into phenetole, $C_6H_5.OC_2H_5$, is 'instantaneous.' The values of the velocity-coefficients, k_{II}, for the second chlorine atom, together with those of the corresponding phenols, are given in the table.

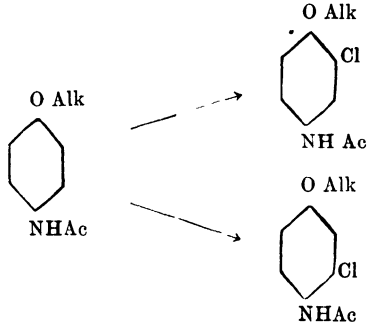
	k_{II}		k_{II}
o-Chlorophenol ...	57	Chloroanisole ...	1·5
p-Chlorophenol ...	32	Chlorophenetole ...	3·0
Acetanilide ...	40	*p*-Chloroacetanilide	0·2

The alkoxy- groups are less active than the hydroxy- groups, but their value is brought out by a comparison with acetanilide and *p*-chloroacetanilide. For acetanilide k_{II} is 40, whilst for anisole and phenetole it is too rapid for measurement ('instantaneous'), that is, over 1,000; and for *p*-chloroacetanilide the value is 0·2 as compared with 1·5 or 3·0 for the ethers.

This high activity of the methoxy- and ethoxy- groups accounts for the high values observed by us [3] in the chlorination of acetoanisidide

[2] Orton and Jones, Reports, 1910; Orton and King, *loc. cit.*
[3] Orton and King, *loc. cit.*

$k_{II} = 60$) and acetophenetidide (k_{II}=90), in each of which are two directing groups, alkoxy- and acetamino-. Moreover, the products of the chlorination should in these compounds be a mixture in which the chloro- compound formed under the influence of the alkoxy- group would largely predominate, thus:



As nothing at the time was known of the activity of the alkoxy-groups in directing substitution, we [4] took the monochlorophenetidide, which we isolated only by repeated crystallisation of the first product, to be 5-chloroacetphenetidide. The relatively greater activity of the ethoxy- group would indicate that the chloro- derivative in larger proportion is the isomeric 2-chloroacetphenetidide. Professor J. F. Thorpe has, moreover, recently prepared the 5-chloroacetphenetidide and demonstrated its constitution undoubtedly, and has further shown that the compound which we isolated is 2-chloroacetphenetidide.

(3) *A Comparison of the Amino- and Hydroxy- Groups.*—A direct comparison between the amino- and hydroxy- groups in their activities in directing chlorination is not very easy to obtain; the speeds of entrance of the first and second atoms of chlorine into aniline and phenol are very high, the introduction of the nitro- group, which lowers the speed of chlorination, is not permissible owing to its specific effect, mentioned in the foregoing, on the hydroxy- group. Moreover, a further difficulty in obtaining an exact relation arises from the great difference in the activities of the two groups. The most trustworthy method is found in the measurement of the rate of entrance of the third chlorine atom into 2:4-dichloroaniline and 2:4-dichlorophenol respectively. The value of k_{II} 18.4° for the aniline is about 600, and that for the phenol approximately 0·16.

Summary.—The amino- group far surpasses all other groups in activity in chlorination of aromatic compounds, and is followed by the groups, hydroxy-, alkoxy-, and acetamino- in the order given.

$$NH_2 > OH > OAlk > NHAc.$$

The Committee ask for reappointment, and for a grant of 10*l.* for the year 1915-16.

[4] Orton and King, *loc. cit.*

The Study of Plant Enzymes, particularly with relation to Oxidation.—Fourth Report of the Committee, consisting of Mr. A. D. HALL (*Chairman*), Dr. E. F. ARMSTRONG (*Secretary*), Professor H. E. ARMSTRONG, Professor F. KEEBLE, *and* Dr. E. J. RUSSELL.

IN the last communication to the Royal Society on Lipase, by Armstrong and Gosney, reference was made to experiments with the seed of *Chelidonium majus*. Further work has been done with this seed to determine its synthetic activity. The results are in harmony with those published in the interval by Bournot, who was the first to recognise the high lipoclastic activity of the seed.

A good deal has been made, during the year, of a discussion by van Slyke and Cullen of the work done with urease, which had led Armstrong and Horton to conclude that the action of this catalyst was not subject to the ordinary mass-action law but practically linear in rate over the greater part of its course. Van Slyke amplifies the ordinary mass-action equation by a term representing the time occupied in the decomposition of the hydrolyte by the enzyme and claims that the results are in accordance with such 'mass-action equation'; but as the mass-action term is admitted to be of no practical account, the argument he develops practically falls to the ground, leaving the position much as it has been stated by E. F. and H. E. Armstrong.

The work of the Committee has been extended in various directions during the year but with no very definite results, as it has been impossible to carry on systematic work.

Correlation of Crystalline Form with Molecular Structure.—Report of the Committee, consisting of Professor W. J. POPE (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Mr. W. BARLOW, *and* Professor W. P. WYNNE.

DURING the year, in addition to a limited amount of crystallographic work, a beginning has been made in determining the molecular volumes of compounds in close crystallographic relationship. The following results are given as examples. It will be seen that there is a fairly regular relationship between the salts:—

Molecular Volumes of Sulphonates.

—	Fe	Co	Ni	Cu
Benzenesulphonate . . .	300·95	298·39	294 73	294·84
Toluene-p-sulphonate . . .	338·14	334·19	330·74	320·80
p-Chlorobenzenesulphonate . .	340 03	337·97	—	317·58
p-Bromobenzenesulphonate . .	—	343·47	339·48	
p-Iodobenzenesulphonate . .	356·32	358·53		

On discussing the crystallographic results in the light of these mole-

cular volume measurements, it appears that throughout the series of salts the morphological alteration in the passage from the benzene-sulphonate to the other salts falls on the axial ratio a : b, the ratio c : b being scarcely altered.

This unexpected result is being followed up.

Plant Products of Victoria.—Interim Report of the Committee, consisting of Professor ORME MASSON (*Chairman*), Dr. HEBER GREEN (*Secretary*), Mr. J. CRONIN, *and* Mr. P. R. H. ST. JOHN, *charged with the Chemical Investigation of Natural Plant Products of Victoria.*

THE work of the Committee has so far been devoted to the study of the essential oils of native shrubs and trees, and has been carried out partly in the laboratory and partly in the field.

(1) An experimental still and a new pattern of condenser have been designed and constructed for the distillation of the essential oil from foliage.

They will take a charge of over one hundredweight of leaves and are specially adapted for the experimental requirements in the bush.

(2) A new pattern of standard flask has been devised and constructed of fused quartz for quantitative fractional distillation of oils in the laboratory.

It is proposed to investigate the applicability of electric heating in connection with this apparatus.

(3) Samples (generally of several hundredweight lots) of important native oil-bearing plants have been collected from various parts of Victoria, partly by taking special trips and bringing sacks of foliage to Melbourne, and also by taking the still into the bush, where a camp was made for about a month and the oils distilled from the plants in their native habitat.

In this way reliable material has been obtained for about twenty species, and although two research assistants engaged in the work have received other appointments, the investigation of these oils is being proceeded with in the laboratory.

(4) Investigations have been completed with regard to two oils, and the results are about to be communicated to the Royal Society of Victoria for publication.

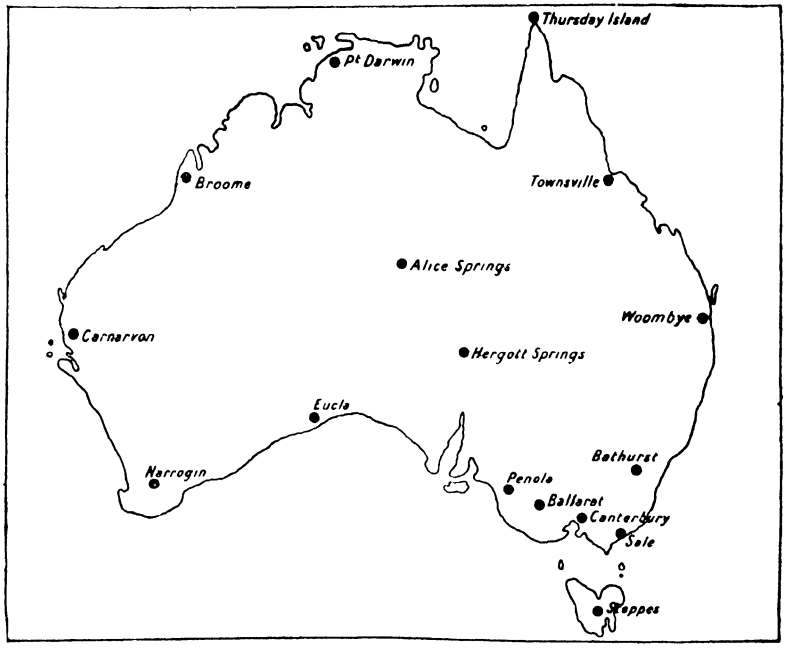
In the case of several others the results will soon be completed, whilst for some species more material is required.

(5) Of the 50*l.* granted to the Committee by the Association and paid over to its Chairman last year, 24*l.* has been spent up to the present. It is proposed to expend the balance on further apparatus and chemicals.

The Committee has the honour to apply for reappointment, as the work is being continued.

The Influence of Weather Conditions upon the Amounts of Nitrogen Acids in the Rainfall and Atmosphere in Australia.—Interim Report of the Committee, consisting of Professor ORME MASSON (*Chairman*), Mr. V. G. ANDERSON (*Secretary*), Mr. D. AVERY, *and* Mr. H. A. HUNT, *appointed for the Investigation thereof.*

THE work undertaken by this Research Committee is a continuation of the work commenced by Mr. V. G. Anderson, who has shown in a paper read before the Chemistry Section at Melbourne, and published in the 'Quarterly Journal of the Royal Meteorological Society' (Vol. xli., April 1915, pp. 99-116), that certain relations exist between the



An Outline Map of Australia, showing approximate positions of Collecting Stations, 1915.

amounts of nitric and nitrous acids in the rainfall, and the weather conditions prevailing at the time the rain-water is collected. Anderson's investigations were confined to rain-water collected near Melbourne, but in the present work it was thought advisable to collect samples of the rainfall from all parts of Australia. With this end in view this Committee has expended the grant entrusted to it in establishing series

of collecting stations at suitable places in the several climatic zones of Australia. The voluntary services of a number of qualified and experienced observers have been secured. The number of stations at present established is sixteen, and these are distributed over the Continent as shown in the attached map (1). Samples of rain-water are now being collected at each station every day on which rain falls.

A great deal will depend on the amount of care bestowed upon the collection of the samples of rain-water. In the choice of agents for collecting the samples the Committee was guided by the advice of one of its members, Mr. H. A. Hunt, Commonwealth Meteorologist, who was able in nearly every case to recommend, from personal knowledge, a resident observer possessing exceptional qualifications for this work. The Committee wishes to place on record an acknowledgment of its indebtedness to the following lady and gentlemen who are so ably and enthusiastically assisting it in carrying on this work:

Miss J. Heinrichsen, Ballarat, Victoria.
S. Hebbard, Esq., Technical School, Sale, Victoria.
A. H. Bisdee, Esq., Wihareja, Steppes, Tasmania.
W. M. Lee Bryce, Esq., The Resident Magistrate, Thursday Island, Queensland.
F. Fairley, Esq., M.I.E.E., F.R.M.S., Woombye, Queensland.
Dr. H. Priestley, Australian Institute of Tropical Medicine, Townsville, Queensland.
R. Gordon Edgell, Esq., Bradwardine, Bathurst, New South Wales.
E. J. Cook, Esq., P.M. Hergott Springs, South Australia.
Simon Ockley, Esq , Comaun, Penola, South Australia.
W. A. Doran, Esq., P.M. Eucla, Western Australia.
G. R. Kirkby, Esq , P.M Carnarvon, Western Australia.
Major G. T. Wood, The Resident Magistrate, Broome, Western Australia
G. G. Lavater, Esq , A.R.V.I A., Narrogin, Western Australia.
Dr. Mapleston, Port Darwin, Northern Territory
J. McKay, Esq., P.M. Alice Springs, Northern Territory (Central).

Each observer is provided with a glass rain-collecting gauge and a set of specially prepared stoppered bottles in which the samples are forwarded. A set of instructions has been drawn up for the guidance of observers in collecting the samples. A copy of these instructions, together with the several enclosures for the use of observers, is appended to this report (Appendix A).

The samples of rain-water are being sent to Melbourne by post. The postal charges, which are naturally very heavy, are being defrayed by the Commonwealth Meteorologist, with the sanction of the Minister of Home Affairs. The Committee desires to express its appreciation of this unsolicited and valuable concession. Special packages had to be devised for sending the bottles through the post. After repeated trials a double cardboard box lined with corrugated paper was found to be satisfactory. Samples are being sent regularly through the post from stations upwards of three thousand miles distant from Melbourne, but up to the present time no breakages have occurred.

In order to deal with the large number of samples to be examined,

the laboratory equipment previously used by Anderson has been added to, provision having been made for the simultaneous evaporation of sixteen samples of water in a specially designed electrically heated water-bath. The methods employed are those used in the previous research, and which are described in a recent number of the 'Quarterly Journal of the Royal Meteorological Society.'

During the period between September 1914 and March 1915 the activities of the Committee were confined chiefly to organisation, including the establishment and equipment of collecting stations, and involving a considerable amount of correspondence with observers and others. On March 15, however, the preliminary arrangements were sufficiently far advanced to permit of samples being collected regularly at all stations, and since that date the scientific work of the Committee has been carried on uninterruptedly. In order that the seasonal variations might be studied, and that the results may be of real value, samples should be collected and examined from all stations until March 1916.

During the progress of the experimental work the results, as soon as they are completed, will be correlated with the meteorological data. In this aspect of the work it will be necessary to draw largely upon the publications of the Meteorological Bureau, particularly in regard to the daily isobaric charts of Australia. The observers are provided with forms for the purpose of making notes of the weather conditions on days when rain is recorded. Sample forms, together with other forms used in tabulating the results, are appended (Appendix B).

Up to the present time no work has been done by the Committee upon the direct determination of the amount of nitrogen peroxide in the atmosphere. The difficulties connected with this work are very considerable owing to the exceedingly small proportion of this gas normally present in air However, it is thought that these difficulties may be overcome, and it is the intention of the Committee to proceed with this phase of the work as soon as possible. Additional apparatus will be required for this purpose.

A list of apparatus in the possession of the Committee is appended (Appendix C).

This Interim Report is submitted with the request that the Committee be reappointed with a further grant of 20*l*., for the purpose of carrying on the investigation outlined in the foregoing pages.

APPENDIX A.

'Ithaca,'
Victoria Avenue,
Canterbury, Vic. :
Feb. 17, 1915.

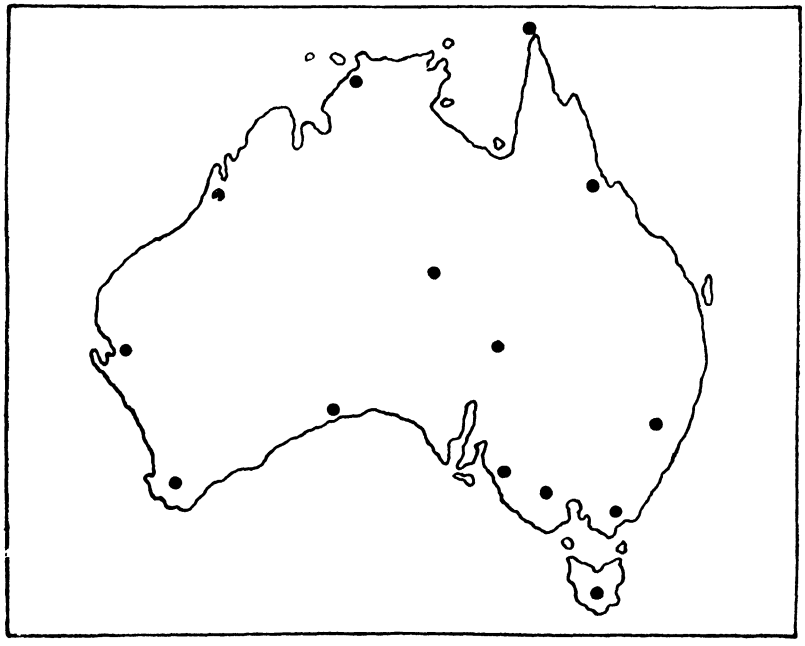
Dear Sir,

The following are enclosed for use in connection with the work of the Research Committee on Nitrogen Acids in Rain-water :—

1. A descriptive list of the apparatus supplied;
2. A list of general instructions;
3. A list of the names and addresses of the Observers who are co-operating with the Research Committee;
4. A map showing the approximate positions of the observing stations;
5. A drawing showing the method of setting up the collecting gauge;

6. A copy of an abstract of the paper read before the Chemistry Section of the British Association Meeting at Melbourne;
7. Twelve one-penny postage stamps to be used for sending the monthly weather returns to the Hon. Secretary at the above address;
8. A stamped and addressed envelope.

I have despatched to you by parcel post parcels [1] containing apparatus as per descriptive list enclosed. Will you kindly let me know immediately you receive them the condition in which they arrive, and whether or not there are



Map showing approximate positions of Collecting Stations.

breakages or shortages? The stamped envelope is provided for this purpose. Any suggestions as to modifications to suit local conditions will be welcomed by the Committee.

Will you please commence collecting the samples of water on March 15 or as soon after as possible? Kindly note that parcels may only be posted without prepayment when they are addressed to the British Association Research Committee, c/o Commonwealth Meteorologist, Central Weather Bureau, Melbourne. All communications directed to my private address must be prepaid as usual.

I am,

Faithfully yours,

Hon. Secretary.

APPARATUS AND ACCESSORIES.

1. *Rain-collecting Apparatus.*

This consists of three parts, as follows :—

(*a*) A glass funnel, 7 inches in diameter;
(*b*) A glass receiving bottle with a capacity of about 4¼ pints;
(*c*) A wooden stand.

[1] Five.

Setting up the Collecting Apparatus.

The stand should be placed in a suitable position and the spikes provided for the purpose driven firmly into the ground through the holes in the base of the stand This method of fixing will serve in most cases, but in localities where wind-storms of extreme violence are not unusual it will be advisable to secure the stand by screwing it down to pegs of wood which have been driven into the earth. The pegs should be about 2 inches by 2 inches in section and at least 12 inches long, and sharpened at the end. The accompanying diagrams show the method of setting up the apparatus and the two methods of securing it.

2. *Sample Bottles.*

These are small glass-stoppered bottles which have been carefully washed out with purest distilled water, and then allow to drain. They should not be unstoppered until samples of rain-water are about to be placed in them, and then the stopper should be replaced as soon as possible. They are contained in specially designed cardboard boxes lined with corrugated strawboard, in which they may be sent through the post office, either singly or in batches, without danger of breakage. To each bottle has been attached a blank label. Regular supplies of sample bottles will be forwarded as required.

3. *Glass Wool.*

A plug of this filtering medium should be placed at the apex of the collecting funnel and should be renewed as often as it becomes soiled through exposure.

4. *Bottle Brush.*

This brush is intended for cleaning the funnel and receiving bottle, and must not on any account be used for other purposes. It should be hung in a convenient place and be kept free from dust and other substances which would contaminate the collecting apparatus.

5. *Stationery and Sundries.*

(*a*) Printed forms for recording weather conditions on rainy days;
(*b*) 1 dozen envelopes;
(*c*) 25 addressed parcel tags for returning samples;
(*d*) Wrapping cord

GENERAL INSTRUCTIONS.

Observers should note that it is of prime importance to guard against the introduction of impurities into the rain-water. The Committee wishes to receive the water as nearly as possible in the condition in which it falls to earth. Contamination is more likely to occur before, or after, a fall than while the rain is actually falling. Dust and smoke particles, grass-seeds, insects, bird-droppings and the like, are likely to foul the funnel and receiver during dry spells, and if these are not completely removed before the rain falls the results of the chemical examination will be misleading Much may be done in minimising this source of error by selecting a suitable position for the collecting apparatus.

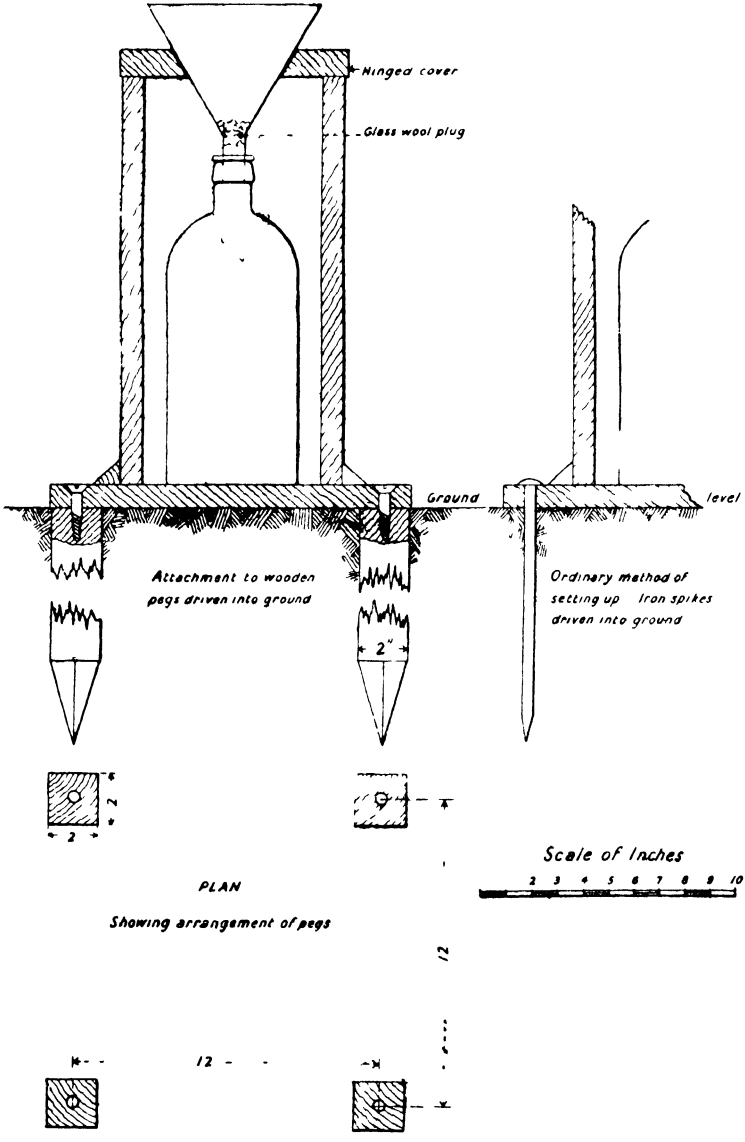
The Position of the Collecting Apparatus.

In choosing a position for the collecting apparatus avoid proximity to buildings, trees, and roads. The rain should be free to fall into the funnel from all points of the compass. The site should, if possible, be enclosed in such a manner as to prevent access by domestic and other animals. An ideal position would be at the centre of a large enclosed grass-plot. The apparatus should not be very far removed from the official rain-gauge, as the measurements made in the latter will be made use of in the research, no measurements being made in the former.

Preparing the Apparatus.

Before placing the funnel and receiver in position they should be rinsed out with rain-water, and allowed to drain for five minutes. Rain-water collected during a very heavy downpour is suitable for this purpose, especially if the

first portions of the shower are rejected Failing this, good tank-water will do, but hard mineral water, or water that is at all discoloured, should on no account be employed On request a large bottle for storing a supply of pure



rain water will be forwarded Washing out with water should be repeated each day when there is a probability of rain When draining the glass-ware care should be taken not to allow any part of the funnel or the neck of the bottle to come into contact with the soil.

Removal of the Sample.

At nine o'clock each morning the rain-water (if any) in the receiver should be mixed thoroughly by swirling. A sample bottle should then be filled to within one-half inch of the stopper. The remainder of the water may now be emptied out or, if the amount is large, it may be stored for rinsing purposes. If there is not sufficient rain-water in the receiver to fill the sample bottle send the whole of it. The label on the bottle should now be marked for identification purposes with :

1. The name of the observing station;
2. The date;
3. The rainfall, as measured in the official rain-gauge.

In replacing the stopper of the sample bottle impart to it a screwing motion, with a slight pressure inwards, until it grips firmly. This will prevent leakage during transit.

Recording.

On each day when rain has fallen observations of the weather conditions *during the previous twenty-four hours* should be recorded on one of the forms provided for this purpose At the end of the month the form should be forwarded to the Hon. Secretary of the Committee. When no rain has occurred during any month the form should be marked ' No rainfall recorded ' and be forwarded as usual. Observers are invited by the Committee to note and place on record any special features of the weather immediately preceding or accompanying falls of rain. When compared with the composition of the rain-water these observations may lead to important conclusions.

Packing and Forwarding.

The bottle containing the sample should be replaced in its box, a printed return tag attached, and the package posted at the first opportunity Each forwarding tag should be marked with :

1. The name of the collecting station;
2 The date of posting.

Should six samples have accumulated before the departure of the next mail they may be placed together in a large box and sent as a single package. The Committee is indebted to the Commonwealth Meteorologist for arranging to have all postal charges in connection with this research paid at Melbourne.

Names and Addresses of the Observers who are co-operating with the Research Committee of the British Association engaged in investigating the Influence of Weather Conditions upon the Amounts of Nitrogen Acids in Rain-water in Australia :

Queensland.

W. M. Lee Bryce, Esq , The Residency, Thursday Island.
F Fairley, Esq., M.I.E E., F.R.M.S., Woombye.
Dr. Henry Priestley, Australian Institute of Tropical Medicine, Townsville.

New South Wales

R Gordon Edgell, Esq , Bradwardine, Bathurst.

Victoria

Miss Jean Heinrichsen, Ballarat.
S. Hebbard, Esq., Technical School, Sale.

Tasmania.

Athol H. Bisdee, Esq., Wihareja, Steppes.

South Australia.

E J Cook, Esq , P.M. Hergott Springs.
Simon Ockley, Esq., Comaun, Penola.

Western Australia.

W. A. Doran, Esq., P.M. Eucla.
G R Kirkby, Esq , P.M. Carnarvon.
Major G. T. Wood, The Residency, Broome.
G. G. Lavater, Esq., A.R.V.I.A., Narrogin.

Northern Territory.

Dr. Mapleston, Darwin.
J. McKay, Esq., P.M. Alice Springs.

APPENDIX B.

Collecting Station at _____

Weather Conditions (on days when rain was recorded) during the month of _____ _____191

Summary of Weather Conditions during 24 hours ending at 9 A.M. on the day the rain was collected.

Date	Rainfall	Wind		Temperature		Pressure		General Remarks
		Direction	Velocity	Max.	Min.	Same Day 9 A.M.	Previous Day 9 A.M.	

Collecting Station at _____ Month of _____ 191

Date	Rainfall (inches)	Nitrogen			Ratio $\frac{N(ic)}{N(ous)}$	Remarks
		Milligrams per 100 Litres	Product	Pounds per 1000 acres		

Collecting Station at _____ Month of _____ 191

Date	Rainfall (inches)	Nitric Nitrogen		Nitrous Nitrogen		Total Oxidised Nitrogen		Ratio $\frac{N(ic)}{N(ous)}$	Weather Type
		Milligrams per 100 Litres	Pounds per 1000 Acres	Milligrams per 100 Litres	Pounds per 1000 Acres	Milligrams per 100 Litres	Pounds per 1000 Acres		

APPENDIX C.

List of Apparatus purchased by the Research Committee on Weather Conditions and Nitrogen Acids in Rainfall, and used in carrying on the work of the Committee.

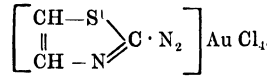
26 doz. 4-oz stoppered bottles;
24 doz. double, lined, cardboard boxes ($2\frac{1}{4}$ inches by $2\frac{1}{4}$ inches by 6 inches);
4 doz. cardboard boxes ($5\frac{1}{4}$ inches by 6 inches by $7\frac{1}{2}$ inches);
16 rain-collecting gauges, complete with wooden stand, iron spikes, funnel, glass container, bottle brush, and $\frac{1}{2}$ oz. of glass wool;
1 sixteen-hole, electrically heated water-bath of copper, complete with wooden stand and attachments;
1 distilling apparatus, consisting of $\frac{1}{2}$-gallon retort of Jena glass, Davies condenser, Liebig's condenser, two retort stands, two clamps and boss-heads, and three yards of $\frac{3}{16}$-inch I.R. tubing;
$2\frac{1}{3}$ doz. glass basins ($3\frac{1}{2}$ inches diameter);
6 doz. Erlenmeyer flasks, of Bohemian glass, 100 c.c capacity;
2 doz. watch-glasses ($1\frac{1}{2}$ inch diameter);
4 Nessler tubes (70 c.c), graduated in cubic centimetres;
2 wooden trays (18 inches by 20 inches);
3 wooden trays ($15\frac{1}{2}$ inches by 14 inches).

Research on Non-aromatic Diazonium Salts.—Interim Report of the Committee, consisting of Dr. F. D. CHATTAWAY (*Chairman*), Professor G. MORGAN (*Secretary*), Mr. P. G. W. BAYLY, *and* Dr. N. V. SIDGWICK.

2-Aminothiazole, produced by the condensation of thiocarbamide and chloro-acetaldehyde alcoholate, is a non-aromatic base exhibiting a certain degree of diazotisability. It was formerly known that in concentrated hydrochloric or hydrobromic acid the base reacted with nitrous acid to yield a very unstable diazo- derivative, not hitherto isolated from solution. This unstable product speedily lost its diazo-nitrogen, giving rise to 2-chlorothiazole or 2-bromothiazole. In feebly acid solution the diazotisation of 2-aminothiazole was known to yield an ill-defined sparingly soluble thiazole-2-diazohydroxide

[With G. V. Monow, Ph.D., A.R.C.Sc.I.]

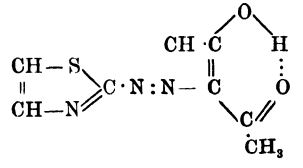
The foregoing observations on the instability of the diazo- derivatives of 2-aminothiazole in the presence of halogen hydrides were confirmed. It was found that 2-aminothiazole is more readily diazotisable without by-products in the presence of oxy- acids. In 20-per-cent. perchloric acid 2-aminothiazole readily dissolves, and the addition to the solution of ethyl nitrite determines the production of thiazole-2-diazonium perchlorate. This salt was not isolated, as it explodes even in dilute ice-cold solutions. The diazotisation of 2-aminothiazole proceeds less readily in dilute nitric acid owing to the sparing solubility of the nitrate of this base. Diazotisation proceeds smoothly in dilute sulphuric acid, the solution remaining colourless and free from decomposition products. On adding sodium aurichloride the orange-yellow crystalline *thiazole*-2-diazonium aurichloride was precipitated.



This salt, which is readily hydrolysed to the unstable diazo-hydroxide by water, is stable when dry at the ordinary temperature.

The foregoing thiazole-2-diazonium salts couple with phenols and reactive aromatic bases, such as β-naphthylamine. They also condense with the β-diketones yielding non-aromatic yellow azo- derivatives.

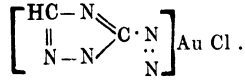
Thiazole-2-azo-acetylacetone



separates in golden-yellow leaflets decomposed on prolonged boiling in alcoholic solution.

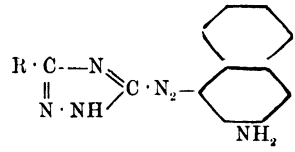
[With J. Reilly, M.A., M.Sc., and W. Caldwell, M.A.]

The diazotisation of 5-amino-1 : 2 : 4-triazole and its homologues has been further investigated. This base is diazotisable to stable diazonium salts in aqueous solutions of the oxy- acids, although in presence of hydrochloric acid 5-chloro-1 : 2 : 4-triazole is the product actually isolated. In aqueous solutions the diazonium oxy- salt slowly deposits an ill-defined substance which, although containing its diazo-nitrogen, no longer couples with alcoholic or alkaline β-naphthol. This product is, however, re-converted into a coupling diazonium salt by dissolving in moderately concentrated nitric or sulphuric acid. On adding auric chloride hydrochloride to the solution of these diazonium oxy- salts, a sparingly soluble crystalline auric chloride derivative is precipitated.



Similar results have been obtained with 5-amino-3-methyl-1 : 2 : 4-triazole. This base gives a stable diazo- solution in the presence of nitric or sulphuric acid. The auric chloride derivative and the non-coupling *iso*-diazo- derivative have been isolated, and are being further investigated.

A comparative study is being made of 5-amino-3-phenyl-1 : 2 : 4-triazole. The diazonium oxy- salts of the bases of the triazole series couple with phenols and the more reactive aromatic bases such as β-naphthyl-amine yielding azo- derivatives soluble in aqueous alkali hydroxides, this property indicating the acidic character of the triazole ring, the imino-hydrogen



being replaceable by metallic radicals.

The Botanical and Chemical Characters of the Eucalypts and their Correlation.—First Report of the Committee, consisting of Professor H. E. ARMSTRONG (*Chairman*), Mr. H. G. SMITH (*Secretary*), Mr. E. C. ANDREWS, Mr. R. T. BAKER, Professor F. O. BOWER, Mr. R. H. CAMBAGE, Professors A. J. EWART *and* C. E. FAWSITT, Dr. HEBER GREEN, Dr. CUTHBERT HALL, Professors ORME MASSON, E. H. RENNIE, *and* R. ROBINSON, *and* Mr. P. R. H. ST. JOHN.

[PLATES V. AND VI.]

THE Committee was appointed at the Australian Meeting in 1914; during the year, Mr. J. H. Maiden has resigned and Professor A. J. Ewart has been made a member; three meetings have been held in Sydney.

The Eucalypts cannot be completely classified according to any one (botanical) character and, at present, the chemical and the botanical characters cannot all be taken into account with sufficient precision to warrant the submission of a classification of the species in the order of their evolution.

The Committee only feel justified in drawing attention to the following conclusions on specific points which may be considered to be well established:—

(1) Three types of venation are met with in the mature lanceolate leaves of the Eucalypts; each of these types appears to be characterised by a definite type of anther in the flower, by special oils in the leaves and by specific substances in the kino from the tree.
(2) The amount of inorganic material present in the wood of the Eucalypts is extremely small in the case of the species which grow to the greatest size.
(3) The evolution of the Eucalypts has been accompanied by a marked evolution in the Cotyledons.
(4) Chemical as well as botanical evidence shows that the Eucalypts are closely related to the Angophoras.

The Botanical and Chemical Characters of the Eucalypts and their Correlation. By R. T. BAKER *and* H. G. SMITH.

The genus Eucalyptus is of great importance in Australia, as it embraces perhaps about two-thirds of the vegetation of the continent; whilst the characteristic botanical features are representative of the whole genus, there are distinct minor differences which justify pronounced differentiation in not a few directions. During recent years the botanical and chemical characters of many species have been determined. It appears that, not only are certain botanical features peculiar

to the genus but that there are corresponding chemical characters which are just as pronounced and sometimes even more constant than the botanical. There is also reason to believe that such botanical and chemical features have been evolved coincidently, in a more or less uniform manner.

Eucalyptus trees take many forms of growth and their botanical features and chemical characters are often most diverse. They are roughly divided vernacularly into groups and sub-groups; the names that are given are largely indicative of certain physical features. Incidentally, it may be mentioned that scientific study has shown that these vernacular groupings hold good in a remarkable manner; thus the terms 'Bloodwood,' 'Peppermint,' 'Ironbark,' 'Stringybark,' 'Ash,' 'Box,' 'Gum,' representative, more or less, of groups, are applied to species having similar and comparatively constant features throughout the whole area of distribution. Other common names, however, are representative only of particular species, *e.g.*, 'Tallow-wood,' 'Spotted Gum,' 'Blue Gum,' 'Red Gum,' &c. Although intended to be distinctive, these are often only so over very restricted areas; the 'Blue Gum' of Tasmania, for instance, is quite distinct from the 'Blue Gum' of Sydney and the 'Red Gum' of one locality is often a species different from that called 'Red Gum' in another district. As an illustration of the way in which the main groups are arranged into sub-groups, the 'Box' group may be mentioned, which is divided vernacularly into 'Red Box,' 'Grey Box,' 'Yellow Box,' &c.; similarly the 'Stringybark' group is subdivided into 'Red Stringybark,' 'White Stringybark,' &c., the 'Ironbark' group into 'White Ironbark,' 'Broad-leaved Ironbark.' It will be obvious that the features of the several species must be of a fairly constant nature, otherwise local nomenclature would be of little use for industrial purposes.

The value of well-marked physical features as an aid to a general classification becomes evident on studying the botanical features of the several species and groups; it is then seen that there is a striking similarity between the several species of the more well-defined groups, the seedling leaves, the anthers, the leaf-venation, all agreeing closely within each group. None the less, although these are often distinctive, there is no well-marked line of separation dividing one group from another; it would seem that there has been uniform development from one species to another throughout the genus, although gaps in the order of agreement naturally occur here and there. It is suggested that the more obvious botanical changes have been mainly due to slow evolutionary development under the influence of environment, soil and climate. Altitude, climate and soil seem to be the chief controlling factors governing the geographical range of most of the species (1). The adaptation of the various species is traceable, largely, to influences of chemical constituents, which under natural conditions, where the struggle for existence is exerted to the fullest, govern the establishment of a species in its earliest stages. It does not seem possible for certain species to grow satisfactorily in soil not congenial to their requirements. Eucalyptus trees vary considerably in size, from the small shrubby forms known as 'Mallees' to those representing some of the largest trees in the world (2).

Directing Influences of Inorganic Chemical Constituents.

The very large Eucalyptus trees of Australia belong to groups the species of which have much in common, both in botanical features and chemical characters. Four of the trees of largest dimensions, growing in Eastern Australia, are *E. regnans*, *E. Delegatensis*, *E. obliqua* and *E. pilularis*; the first three are common both to Australia and Tasmania. The bark of all these is more or less of a 'stringy' nature in cases in which it persists but the trees are mostly 'half-barked,' the upper portions being smooth, hence in some respects they appear to be associated with the true 'Stringybarks,' *E. eugenioides*, *E. macrorrhyncha*, &c., as well as with the class known as 'Gums.' The anthers of these big trees are kidney-shaped (Renantheræ); they all have the leaf-venation indicative of phellandrene, which constituent they all contain in smaller or greater amount; the cotyledons of the seedlings are all similar in shape. The large trees mostly grow in soil comparatively poor in mineral constituents, the soil being of a siliceous nature. The apparent difficulty of trees so placed is overcome, as they have the peculiarity of only storing minute quantities of mineral constituents in their timber (3); this appears to be one of the chief reasons why such trees are able to continue growing until they reach very great dimensions: *E. regnans*, for instance, sometimes exceeds 70 feet in circumference and reaches a height of over 300 feet. If species growing in highly siliceous country stored mineral matter in the woody portions as freely as do the Eucalypts which grow on less siliceous or on basic soils, this available mineral material would soon be exhausted and the growth of the tree would cease; but some of the largest trees of these species must be many hundreds of years old.

The mineral matter stored in the timber of the four above-named species, calculated on the anhydrous timber, is as follows (3):—

E. regnans	0·054 per cent.
E. Delegatensis	0·038 ,,
E. obliqua	0·025 ,,
E. pilularis	0·052 ,,

These values are obtained from timbers collected from five widely distributed localities.

Although the amount of ash constituents in the woody portions of the species referred to is so small, a much larger quantity is found in their leaves, those of *E. regnans* giving 2.85 per cent. of ash, those of *E. pilularis* 2.91 per cent.

The buds, petioles, seed-cases and seeds also contain a considerable amount of mineral matter; thus in the case of *E. pilularis*:—

Buds with petioles	3·79 per cent.
Seed-cases (fruits)	2·89 ,,
Seeds	1·04 ,,

The mineral matter in these portions of the tree, like that of the leaves, would obviously be available for repeated use.

A striking peculiarity of several groups of Eucalypts is the comparative constancy of the amount of manganese in the ash of the timber of a given species from trees grown over the whole range covered by

the species; thus the amount found in *E. pilularis* from five widely distributed localities ranged between 0·2 and 0·26 per cent.; *E. regnans* gave 0·27 per cent.; *E. Delegatensis* 0·3 per cent.; *E. obliqua* 0·22 per cent.

The mean results obtained in the case of these four species show that the manganese present in their timber represents only one part in about one million parts of anhydrous wood; in five species of 'Ironbarks,' it is one part in 60,000 parts (3). Again in the case of this group, whatever the variation in the percentage amount of ash in the timber of the several species of the group, the ratio of Mn to the other inorganic constituents is remarkably uniform; the following are results obtained with the five principal 'Ironbarks':—

	Per cent. of ash.	Per cent. of Mn in ash.
E. paniculata	0·47	1·40
E. siderophloia	0·17	1·25
E. melanophloia	0·172	1·50
E. sideroxylon	0·072	1·15
E. crebra	0·06	1·50

The indications these ash results afford is that *E. crebra* and to a lesser extent *E. sideroxylon* would be found growing naturally on soils more siliceous than that consonant with the other species of 'Ironbarks': this is fairly borne out by results. [The exudations or kinos of the big Australian Eucalypts, previously mentioned, are all similar, their tannins giving a violet colouration with ferric chloride. They all gelatinise readily under suitable conditions and contain neither Aromadendrin nor Eudesmin nor any other crystallisable substance.]

There are considerable differences in the general character of other mineral constituents of the several groups of Eucalypts as well as in the amount of mineral matter stored but there is an approximate relative constancy in the amounts of certain elements required by the members of the several groups. Magnesium is a pronounced constituent in the ashes of species belonging to some groups, whilst calcium predominates in those of others. Representative species of the three large groups, the 'Boxes,' the 'Ironbarks' and the 'Ashes,' show this fact somewhat clearly; the results in each case with members of the same groups agree closely.

'Boxes.' *E. hemiphloia* and *E. albens*:—

	Mean percentage in ash.
CaO	51·31
MgO	2·13

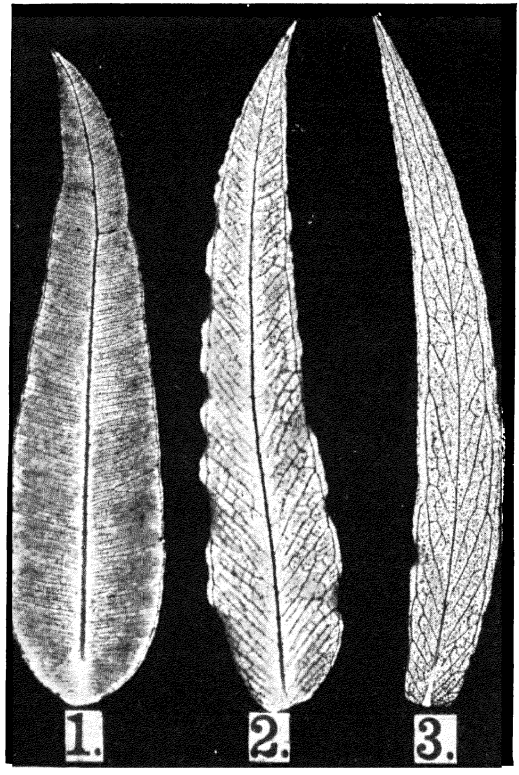
'Ironbarks.' *E. siderophloia* and *E. paniculata*:—

	Mean percentage in ash.
CaO	29·63
MgO	6·92

'Ashes.' *E. Delegatensis* and *E. regnans*:—

	Mean percentage in ash.
CaO	16·11
MgO	21·76

In a large number of the species in which calcium is the pronounced mineral constituent, oxalic acid is a characteristic product of metabolism;



Types of Eucalyptus Leaf-Venation (leaves used as negatives)

1 *E corymbosa* 2 *E Smithii.* 3. *E. amygdalina.*

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in some Eucalypts, this is formed in such quantity that at times as much as one-sixth of the air-dried bark consists of crystallised calcium oxalate (4), showing plentifully a form of twinning in geniculate crystals. The tannin stored in the barks of these oxalic acid forming species is of good quality for tanning purposes and affords a very good tanning extract; it might be profitable, therefore, to work some of these barks for this material—oxalic acid could then be obtained in quantity, as a by-product, from the residues. *E. salubris*, of Western Australia, is a species which might be so worked. The chemistry and botanical features of *E. salubris* show it to be closely associated with the class of Eucalypts known as 'Mallees,' trees which form the short stunted vegetation or 'Mallee Scrub' extending over much of Australia. In these 'Mallee' species lime is a dominant mineral constituent and they all form oxalic acid in abundance, the one factor, perhaps, being the corollary of the other. It is hardly to be expected that species which produce oxalic acid in abundance would live long enough to form very large trees, so that the tendency to develop a shrub form may have been brought about through adverse chemical influences operating in these groups; and it is interesting to find magnesium in such quantity in the ashes of Eucalyptus which reach a very large size, particularly as such trees only store mineral matter in their timbers to the extent of about one pound to 2,000 pounds of anhydrous wood. It is thus seen that the amount of any element is small, the CaO representing in *E. regnans* about one 15,000th part of the weight of the moisture-free timber and the MgO about one 10,000th part.

Essential Oils.—The essential oils of the numerous Eucalyptus species vary in composition in a striking degree but the variation is of a remarkably uniform character (5) and apparently has been contemporaneous with distinctive botanical changes; this is strongly brought out by the progressive alteration in the veins of the mature lanceolate leaves (6), starting from the featherlike venation of the members of the *Corymbosæ* group, through the intermediate form representative of the members of the cineol-pinene group, to the looping or butterfly-wing venation of the leaves of the 'Peppermints' and the 'Ashes,' a form indicative of the presence of the terpene phellandrene. These three types of leaves are shown in the accompanying Plate V.:—

The varying thicknesses of the midribs: the disposition of the marginal veins; the second vein in No. 3; and the varying amount of oil-glands in these pictures should all be noted.

The first type is represented by the Angophoras and by certain Eucalypts, between which there is general chemical agreement. The terpene in the oils of the species of Eucalyptus characterised by this venation and also in the Angophoras is pinene; phellandrene does not occur in them and cineol is either absent or only present in small amount, whilst the yield of oil is always small. The second type of venation is characteristic of the species which yield oils consisting of pinene and cineol; the oils richest in cineol are obtained from leaves having this venation; it is well shown in such species as *E. globulus*, *E. Bridgesiana*, *E. goniocalyx*, *E. Smithii*, &c. Oils derived from species with this venation do not contain phellandrene; as the lateral

veins are farther apart than are those of the first group, more room for oil-glands is available, so that, as a rule, a greater yield of oil is obtained from the members of the second group than from those of the first. Although only a comparatively few species of the second group are utilised commercially on account of their oil, for various reasons—such as yield, quantity available, accessibility, &c.—many other species besides those worked contain oils equal in value to the most pronounced cineol-bearing species made use of. It must be apparent that even a slight decrease in yield would be sufficient to exclude a species from commercial exploitation, although the constituents might be identical with those of the more prolific-yielding varieties. It is a fact worthy of notice that the yield of oil from each particular species, wherever found, is comparatively constant, although ranging from about 4½ per cent. to practically nothing. This naturally is a factor of some commercial importance, as well as of scientific interest as proof of the comparative constancy in the quantity of oil formed.

The third group contains the species which yield oils in which the terpene phellandrene is an important constituent. This group now supplies most of the oil used so largely in the separation of metallic sulphides by the flotation process.

Although the phellandrene-bearing oils are not at present in favour for pharmaceutical purposes, some species which contain much phellandrene are also rich in cineol. This is the case particularly with the oils of *E. linearis* and *E. Risdoni* (7), species allied to the 'Peppermint' group. The question of the therapeutic values of the several types of Eucalyptus oils is still an open one; it does not follow that the cineol-pinene oils are necessarily of more value in this direction than are the cineol-phellandrene oils (8), particularly as the other constituents differ considerably in the two classes and it is known that the first Eucalyptus oil distilled by Dr. White in 1788 (9), of the medicinal value of which he speaks so highly, was obtained from the leaves of a member of the cineol-phellandrene group in which the venation corresponds to that of No. 3 in the photograph.

Such Eucalyptus oils as those derived from *E. polybractea* and from *E. cneorifolia* contain a phenol different from that found in the oils of the 'Peppermint' group (10), together with an aldehyde of high boiling-point (either cumin aldehyde or aromadendral*) and a minimum proportion of esters. In the richer cineol-phellandrene oils, the ester butylic-butyrate occurs in some quantity (11) and the phenol (Tasmanol) they contain is not identical with that found in the oils of the other group, whilst the ketone (piperitone) takes the place of the aldehyde aromadendral and a larger proportion of ester is usually present. Eucalyptus oils so diverse in chemical constituents cannot have equal therapeutic value.

The question of the purification of the crude oils required for medi-

* Although Messrs. Schimmel and Co. assert that cumin aldehyde is the aldehyde of this class occurring in Eucalyptus oil, the high lævorotation shown by this aldehyde extracted from the oils of some species is alone sufficient to show that Aromadendral and cumin aldehyde cannot be identical substances. As the latter aldehyde does not contain an asymmetric carbon atom, it does not show optical activity.

cinal purposes thus becomes of some importance and it might be worthy of consideration whether mechanical or chemical means might not be more advantageously used than the ordinary method of distillation. The two largest groups will always supply the Eucalyptus oils to be used for pharmaceutical purposes; as the botanical and chemical peculiarities of individual species are uniform to a remarkable degree, constancy in results can be assured.

The data that have been collected in Australia regarding oils of undoubted species show that the product of a particular species, growing under natural conditions, is remarkably uniform in character and even when commercially distilled should show physical and chemical results within a stipulated range.

The herbarium material of the two species *E. Maculata* and *E. citriodora* show close morphological resemblances, yet the oils differ entirely, that from the latter species consisting almost wholly of the aldehyde *citronellal*, which is not present in that from the former. This is not an accidental circumstance due to location, because the uniformity in constituents with both is well shown. The causes responsible for this result are not evident from a morphological study but lie deeper and may eventually be traced to chemical influences acting along special lines. This is one of the few instances met with among the Eucalypts in which close botanical resemblances are not associated with a corresponding similarity in the chemical composition of their oils.

The oil from *E. Macarthuri* consists very largely of geranylacetate and geraniol (12), the ester content often exceeding 70 per cent., so that this species also appears to be a departure. The ester geranylacetate had its origin apparently in the Angophoras (13) or even perhaps in an older genus; it is found in small amount in the oils of many Eucalyptus species having general botanical features allied to those of Angophora but the passage forms to *E. Macarthuri* appear to be wanting.

Another instance is the citral-limonene bearing oil of *E. Staigeriana*, in which case again the connecting species have not been found. These instances are, however, few in a genus so rich in the number of species.

The rule appears to be that each chemical constituent in the Eucalypts increases in amount through a range of species until it reaches a maximum in one of them, so that in the case of these apparently anomalous species an explanation is forthcoming; they certainly show a maximum in the characteristic constituents their oils contain. The pinenes, cineol, phellandrene, particular esters, oxalic acid, Eudesmin, Armadendrin, the various tannins, as well as other chemical constituents, all appear to follow this rule; as corresponding botanical features are also shown, an evolutionary theory for the formation of the species of the whole genus is strongly supported both by botanical and by chemical evidence.

Kinos or Astringent Exudations.—It has been stated already that the essential oils of particular species of Eucalyptus show a remarkable uniformity in constituents as well as in general physical characters; advantage has been taken of this chemical constancy in the direction of assisting botanical studies in the genus, so that more correct values

might be attached to particular botanical features peculiar to certain species or groups.

A corresponding comparative constancy in chemical characters is also evident in the case of the kinos or exudations of the several species; these, in most instances, show a grouping parallel with that of particular constituents of the essential oils and are therefore in conformity with certain characteristic botanical features of the species. In fact, this botanical and chemical agreement appears to be represented by practically all the members of the genus.

The suggested evolutionary development of the Eucalypts receives considerable support from the study of these exudations, as there is as much diversity in the chemical composition of the kinos as has been found to be the case in their oils (14).

The exudations of the Eucalypts do not contain gum but are all astringent and contain tannins. These tannins, however, differ considerably from one end of the genus to the other; both in relative astringency and in rapidity of gelatinisation they are widely separated, and this variation is also obvious in the case of the other constituents of the exudations, both crystalline and amorphous.

Some of the members of the genus Angophora show a very close affinity, both botanically and chemically, with those members of the genus Eucalyptus which are included under what is generally known as the 'Bloodwood' group. This relationship is indicated by the general appearance of the tree, by the venations of the lancellate leaves, by the composition of the essential oils, by the presence of caoutchouc covering the very young leaves, and by the composition of the kinos or exudations. The kinos of most of the Angophoras and of some Eucalypts having a similar leaf-venation, *E. calophylla* for instance, contain the crystalline substance Aromadendrin, the other crystalline body found in some Eucalyptus kinos (Eudesmin) being absent (15). The terpene in the leaf-oils is pinene but neither phellandrene nor cineol is present, except in small amount; the leaf-venations resemble the general markings of a feather. The anthers of this group are parallel antheræ; the cotyledons of the seedlings are large and broad. As the leaf-venation in the Eucalypts changes into the peculiar arrangement characteristic of species yielding cineol-bearing oils, Eudesmin is found in their kinos and this substance increases in amount by easy stages through the several species until, in the kinos of the typical boxes—*E. hemiphloia*, for instance—about 10 per cent., is present. Aromadendrin also occurs in these; no Eucalyptus kino so far tested in which Eudesmin is found has been without Aromadendrin. The anthers in this large group are not all parallel but show variations; the cotyledons of the seedlings also vary much in size and shape. As the leaf-venation changes into the peculiar structure indicative of the phellandrene-bearing oils the constitution of the kinos also changes; both Eudesmin and Aromadendrin are absent from all the typical kinos of this group; the colour given by the tannins with ferric chloride differs considerably from that shown by the kinos of the members of the other groups. The anthers of the species belonging to this group are kidney-shaped (Renantheræ). The rapidity with which the kinos of this group gelatinise in tinctures is

also a distinguishing feature; the test is carried out by adding formaldehyde to the solution (16). Although to the taste and by their behaviour on oxidation with potassium permanganate, the kinos of this group appear to be the most astringent, the affinity of their tannins for hide substance is very slight and the barks of these Eucalypts are of little use for leather manufacture. Eucalyptus species the barks of which can be used commercially for tanning purposes, the 'Mallee,' *E. occidentalis*, for instance, yield kinos in which Eudesmin and Aromadendrin both occur; the tannins of this group have great affinity for hide substance and are rapidly absorbed by it. The kinos of the 'Ironbarks' and of a few other species are not soluble in alcohol, though readily so in water; they consist largely of a peculiar tannin glucoside which on hydrolysis forms a deep purplish-brown powder having considerable dyeing power (17). When these kinos are dissolved in water and alcohol is added in quantity insufficient to cause precipitation, they gelatinise readily when treated with formaldehyde; they have little affinity for hide substance and, although plentifully distributed throughout the barks of some species, *E. crebra* and *E. sideroxylon* for instance, have little present commercial value.

A tincture of official strength, made with the kino of *E. calophylla*, is the best possible of all similar substances for pharmaceutical purposes, because it does not gelatinise in tinctures no matter how long the tincture may be kept, whilst the tannin it contains is highly astringent; the material can be obtained in very large quantities. *E. microcorys* would also make an excellent tincture but the kino is difficult to collect. The kino of the 'Red Gum,' *E. rostrata*, although official, is not so well suited for the manufacture of tinctures as those already mentioned but may, nevertheless, be considered of fair quality for the purpose; it is also obtainable in some quantity but it is deficient in astringency and is not so resistent to gelatinisation. The exudations of the Eucalypts thus contain substances showing very great variability and no general considerations can be made to fit all the facts. Chemical constituents found in the exudations of the members of one group, such as the 'Boxes' for instance, are not found in those of some other groups. Tannins characteristic of the kinos at one end of the genus have disappeared at the other, astringent bodies of a different nature taking their place. Yet, with all these differences, there is considerable uniformity in progressive alteration, which is in accord with the varying botanical characters exhibited by the members of this large genus. The kinos in which Eudesmin occurs consist largely of catechol tannins and Eudesmin itself is a catechol derivative containing four methoxy-groups in two veratrol nuclei.

Other Chemical Constituents.—There are a few chemical constituents in the Eucalypts which at present do not appear to be closely associated with corresponding botanical distinctive features, as already shown in many specific instances. Perhaps, however, the reason is that sufficient work has not yet been undertaken in the direction of attempting to decide this point. Myrticolorin, the quercetin glucoside (18), found in such large quantity in the leaves of *E. macrorrhyncha*, is a case in point, as the leaves of some other members of the 'Stringybark' group do not contain this substance.

A few constituents of the oils have apparently no distinctive botanical support; such is the (solid) paraffin (19) which has already been isolated from such diverse species as *E. acervula* and *E. Smithii*. This paraffin appears to be a constant constituent in the oil of the latter species; when purified it melts at 64° C. but that isolated from *E. acervula* melts at 55° C. Further research, however, may show distinctive characters here also.

Eudesmol, the chief stearoptene of Eucalyptus oils, occurs in those derived from different groups but is found in greatest abundance in species yielding phellandrene in quantity, although it also occurs in the oil of *E. Macarthuri* from which phellandrene is absent.

It is necessary that these rarer chemical constituents should be more fully investigated and isolated from the species containing them; it might then be possible to establish definite rules, both botanical and chemical, to account for their occurrence and so bring them into conformity with those other botanical and chemical characteristics the co-ordination of which has now been fairly well established.

The Development of the Genus Eucalyptus. *By* R. H. CAMBAGE.

The earliest evidence we have of the existence of the genus Eucalyptus in Australia is that furnished by the fossil leaves and what are regarded as authentic specimens have been found as far back as in the Miocene period. The Mornington Beds of Victoria, from which Eucalyptus fossils have been obtained, are doubtfully referred to the Eocene period (20). In early Miocene times our present mountain system had not been developed and the climate was mild to warm (21). Eastern Australia was then fairly level and was largely composed of siliceous soils, much of the silica being in a free state and the soils sandy. Subsequent lava-flows and deposits of volcanic tuffs gave rise to a more basic soil; the final uplift, parallel to the east coast, towards the close of the Tertiary, produced elevations which have a cold climate.

The effect of geological formation upon the distribution of the Eucalypts, though distinctly evident in many localities, is to some extent of a local nature, being dominated by the influence of climate. Broadly speaking, Eucalypts are distributed between two extreme types of geological formations, the siliceous and the basic; there are numerous examples of different species approaching each other up to a common boundary without intermingling—some growing on a siliceous granite or sandstone formation, in which there is an abundance of free silica, others on a basalt or other basic rock, giving rise to a clay soil (1). Many of the Eucalypts, including those which are now regarded as the oldest living types, require a soil derived from rocks containing upwards of 70 per cent. silica.

The final uplift throughout Eastern Australia had considerable effect upon the Eucalypts of that area. The resultant Main Divide separated the original uniform climate into three; with its fairly steep eastern face presented to the ocean, it created moister conditions over the coastal area, cooler conditions on the mountains, whilst upon the lower portions of the western side the effect was to produce a drier as well as a hotter summer and colder winter climate. The Eucalypts, towards the

interior, west of the Main Divide, in response to this change, have gradually been adapted to the new conditions, the result being that they differ considerably from many of the coastal species and most of all from those on the higher mountains. None of the Eucalypts of the interior occur in Tasmania.

The Eucalypts belong to a family whose leaves are normally opposite and horizontal; they are also closely allied to the genus Angophora. The ' Bloodwood ' group of Eucalypts show the greatest resemblance to the Angophoras, both as regards leaves and oil contents; they may, therefore, be regarded as representing the type of the oldest Eucalypts now living. They grow in sandy soil and avoid the cold. Apparently, the early Eucalypts flourished in a sandy soil with a warm climate, probably in Northern Australia. The bark was scaly to rough; the leaves were opposite and horizontal and often covered with stellate hairs (22) or coated with caoutchouc; the leaf-venation was transverse, the numerous lateral veins forming an angle of upwards of about 65° with the midrib; the flowers were generally large as compared with those of the genus at the present day and possessed anthers which opened longitudinally in parallel slits (Parallelantheræ); the fruits were generally larger than those of the more recent species of to-day; the chief constituent of the essential oils contained in the leaves was pinene (5). Following some alteration in environment, partly climatic and partly through the advent of more basic soils resulting from volcanic outpourings, a new development took place in the genus and species were evolved with various kinds of bark (hard-furrowed, fibrous, or smooth barks). The mature leaves, which now showed a more oblique or diagonal venation and were alternate, had gradually developed petioles, which allowed them to hang vertically, so as to present the least possible surface to the sun and thus minimise transpiration, whilst those which remained sessile became protected with a glaucous powdery wax or a thickened epidermis. Some species of this new type—the ' Box ' trees amongst others, many of which flourish on the more basic soils—possessed anthers which opened in terminal pores (porantheræ), and cineol now became an important constituent of the essential oils. As the genus encountered colder conditions, partly through spreading southwards and partly through ascending the mountains which were uplifted in Eastern Australia towards the close of the Tertiary period, a further group was evolved having leaves with almost parallel venation or with the now much reduced number of lateral veins at an angle of less than about 25 degrees with the midrib, kidney-shaped anthers with the cells divergent at the base and confluent at the summit (Renantheræ); the essential oils in the leaves contained much phellandrene and little, if any, pinene. This group is largely represented by the ' Peppermint ' trees. On comparing seedling and adult foliage, evidence of transition in leaf form is found in nearly all species; in the cooler country types, such as *E. coriacea* and *E. stellulata*, the lateral veins of the seedling foliage are arranged at angles up to 50 degrees with the midrib, whilst in mature leaves the angles are less than 10 degrees and in most cases the veins are practically parallel with the midrib.

This appears to be the newest group of Eucalypts; they have been evolved in the southern or cool and moist regions. Owing to the final uplift which formed the Main Divide, north and south, and perhaps assisted by the Pleistocene glaciation period, this type has been able to migrate northwards along the higher portions of the range to the borders of Queensland (1).

Eucalyptus leaves with transverse venation are absent from Tasmania and are confined to a very small portion of north-eastern Victoria. They are found practically below the 3,000-feet level in New South Wales but are common on siliceous soils in Northern Australia, thus showing a preference for the warmer climate. Eucalyptus trees possessing leaves with parallel venation occur in Tasmania, Victoria and Eastern New South Wales, whilst in Northern New South Wales their home is above the 3,000-feet level; they are absent from Northern and Western Australia but are found at the highest level at which any Eucalyptus grows in Australia, viz. 6,500 feet, thus showing a preference for cold and moist conditions.

Briefly, then, we have the early Eucalypts growing in a sandy soil with a warm climate, with leaves containing pinene and characterised by a transverse venation, the anthers belonging to the section Parallelantheræ.

Secondly—partly as a result of alteration in climate and partly from the presence of more basic soils, perhaps also the influence of other causes—a new type was evolved in which cineol became an important constituent of the oil, the leaves having a more oblique venation, the anthers opening in parallel slits or terminal pores.

Thirdly—chiefly as a result of the Eucalypts migrating to southern cooler latitudes and climbing up the newly uplifted mountains—a further type was evolved; many of the species contained much phellandrene, pinene being either absent or reduced to a trace; in this type the leaves commonly have parallel venation and the anthers usually belong to the section Renantheræ.

The Correlation between Specific Characters of the Tasmanian and Australian Eucalypts. *By* R. T. Baker *and* H. G. Smith.

In a letter which the late Sir Joseph Dalton Hooker wrote to us he expressed a wish to see a research undertaken to investigate what affinities, if any, there were between the Gum-trees of the mainland and those of Tasmania; being particularly interested in the subject, having described and collected species from the higher altitudes of that island, he regretted he had not been able to collect material at corresponding heights of Australia for the purpose of comparison.

This investigation has been undertaken by us and the results are of more than passing scientific interest, as it is found that when a species occurs both in Tasmania and on the opposite mainland it has not only identical morphological but also similar chemical characters; some species and even groups of wide geographical range on the mainland are found, however, to be absent from the daughter island (23).

The absence or presence of these species seems to be accounted for on tracing out the evolution of the Genus. In our work on the

Eucalypts, published in 1902, the ' Bloodwoods ' are placed as the oldest section of the whole genus; trees having the venation of the ' Bloodwoods ' occur more plentifully in West Australia and sweep right round the north of the continent to one or two outliers in the south-eastern corner of New South Wales; all have red timber.

Following the evolution along this geographical line, the different groups are met with in succession and it is apparent that in Victoria white timbers predominate to the almost entire exclusion of redwoods. On crossing to Tasmania, this distinction is more pronounced, not a single redwood Eucalypt occurring there. In Tasmania again not a single representative of the important group known commonly as the ' Boxes ' is to be found.

The venation is also correlative and so are the essential oils and the kinos. Thus the greatest affinity of Tasmania Eucalypts is with those of Victoria and, along with those of Victoria and New South Wales, they are the more recent of the genus.

The two species, *E. Gunnii* and *E. Perriniana*, of the highest altitudes of Tasmania and Victoria, show specifically remarkable similarities in botanical and chemical characters, although growing so far apart, the sea also intervening.

The oil constituents of these two species vary considerably in both localities but are practically constant in a given species, whether it grow in the higher portions of New South Wales or in Tasmania. The somewhat large amount of the ester butylic-butyrate in the oil of *E. Perriniana*, together with an increased amount of cineol and a comparative absence of phellandrene, seem to be distinguishing chemical features in the case of these two closely agreeing species, which, judging both from botanical and chemical evidence, cannot be identical.

As this land separation has now existed through a long period of time, some of the species common to both localities show a slight variation or departure from the type. *E. amygdalina* of Tasmania differs from the mainland variety in its larger leaves and fruits and in chemical constituents; also, *E. acervula* is most probably a changing form of *E. paludosa*, *E. phlebophylla* a divergence from *E. coriacea* and *E. virgata* from *E. Sieberiana*.

The majority of the Eucalyptus species of Tasmania, therefore, show a marked correlation with those of South-Eastern Australia; this correlation is pronounced in the case of species growing at the lower as well as the higher levels.

It is generally recognised that trees descend to lower levels as the climate changes to colder conditions; the Eucalypts are no exception to this rule. *E. regnans* is found in Victoria growing at fairly high elevations, whilst in Tasmania it flourishes almost at the sea-level; *E. Delegatensis* is rarely found below 4,000 feet in Victoria and New South Wales, yet grows between 2,000 and 3,000 feet in Tasmania.

The Cotyledons and Seedling Leaves of the Eucalypts.

By CUTHBERT HALL.

The study which I have recently published (24) disclosed, as the result of a comparative consideration of a large number of species, that

the cotyledons are of great importance in the differentiation of species. The form and size are constant in each species and do not vary, except within narrow limits which may rather be termed fluctuations. Lubbock says that the cotyledons of most species are entire. In the Eucalypts the emarginate form is the more common. Hence we get two great classes, the entire and the emarginate, the former being the more primitive type. In the size of the cotyledons, the species differ greatly, at one end of the scale being the exceedingly large ones of *E. calophylla*, R.Br. and about 2·5 cm. broad, at the other the very small ones of *E. acaciæformis*, 0·2 cm. broad. The original Eucalypts, represented now by those of the *E. corymbosa* class, had large entire reniform cotyledons; these are practically identical with those of the nearly related genus Angophora. The evidence of the seedlings thus bears out the chemical and morphological evidence as to the near relationship of the two genera. The group of 'Stringybarks,' represented in *E. obliqua* and its allies, also have seedlings with entire reniform cotyledons; these are usually much smaller than those of the preceding group But the interesting fact is to be noted that whilst the members of the corymbosa group elaborate an oil of a simpler composition, resembling the oil found in the Angophoras, its principal constituent being pinene, in the case of the 'Stringybarks' some species, such as *E. lævopinea* and *E. dextropinea*, afford a pinene oil, whilst *E. euqenioides* yields a pinene-cineol oil, *E. macrorrhyncha*, *E. capitellata* and *E. nigra* a pinene-cineol-phellandrene oil and *E. obliqua* a phellandrene-aromadendral oil. It will thus be seen that whilst the bark, anthers (all these have reniform anthers as compared with the parallel anthers of the corymbosæ) and cotyledons have remained stable, a great evolutionary change has occurred in the oils. Whether hybridisation has played a part in this we cannot as yet say.

Among the entire cotyledons, there is yet another small group consisting of species with small circular or reniform cotyledons. These are probably derived from an ancestor in which emargination was present but in the process of reduction in size this has been lost. The fact that they all give a cineol oil also points to such a conclusion.

Of great interest is the important class of Eucalypts with emarginate cotyledons. Whether we have any of the species in which this emargination first appeared, it is hard to say; but this much is probable, that, until it appeared, the Eucalypts were unable to migrate from the warm moist coastal areas to the dry interior, to grow on any but a sandstone formation or to elaborate any but a simple oil not containing cineol. One of the first steps in the evolutionary development of the Eucalypts, whereby they became adapted to all the vicissitudes of Australian physical conditions, has been the development and improvement of the emarginate cotyledons. It is probable that the change first took place in some such species as *E. marginata*, Sm., of Western Australia; this has a large cotyledon with well-marked emargination but the oil is of the simpler pinene type. This group is not large and evidently the large emarginate cotyledon type could not exist away from the moist coastal region any more than the large entire cotyledon type. I am not aware of the character of the soil in which the members

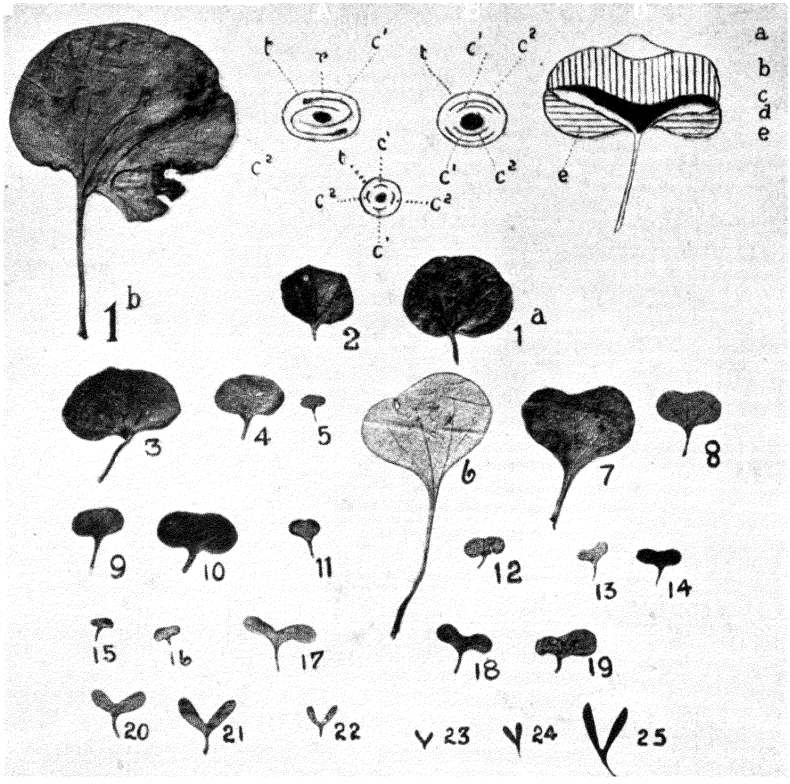
of this group—viz. *E. marginata*, *E. Todliana*, *E. megacarpa*, and *E. santalifolia*—prefer to grow but it would be interesting to find out. The group commonly known as the 'Peppermints,' comprising *E. piperita* and its allies, has a very characteristic type of cotyledon; it is usually of medium size, more or less quadrilateral, with rounded lobes and the emargination is slight or almost absent. The stem and under-surface of cotyledons and primary leaves are characterised by a deep purplish colouration. It may be that the origin of this group is through *E. Planchoniana* or a near relation thereof. This species has a large cotyledon, emarginate and cuneate at base; it is the one exception in the group in having parallel anthers instead of reniform. As is well known, it occurs along the eastern coast in Northern New South Wales and Queensland. It is interesting to note that, in this group, the cotyledons diminish in size in the species growing at the highest altitudes.

There remain now the emarginate cotyledon Eucalypts with cotyledons of medium or small size and emargination slight or very extreme. Under this heading come about half the species of Eucalypts and the majority of interior or dry country species. Some of them, with larger divergent-lobed cotyledons, such as *E. globulus* and its allies, prefer a cool moist mountain climate; many, however, have either very small cotyledons with little or no emargination or else Y-shaped cotyledons in which the lobes of the laminæ are almost linear and the emargination so extreme as to make the cotyledon of the shape of the letter Y. The species with such cotyledons, or very small cotyledons, are mainly dry country species. Practically all these Eucalypts contain cineol in fair amount; most of them contain pinene, some of them aromadendral, a few phellandrene but none of them contain piperitone in their oils. The Y-shaped cotyledon Eucalypts probably originated in Western Australia, possibly from *E. cornuta* or its allies; they then spread east along the Great Australian Bight but they do not seem to have crossed the Dividing Range, except in one instance, *E. squamosa* being found in the neighbourhood of Sydney on the Hawkesbury Sandstone. As it is also found at Rylstone on the Western slopes of the Divide, it has probably reached the eastern coast from the west. This species appear only just to maintain a precarious existence, as the moist coastal conditions do not suit it well. Concurrently with the alteration of the size and shape of the cotyledon leaves there has been an alteration in the size and shape of the fruits. In the Corymbosa group the urn-shaped fruit, with its narrower neck and everted rim, is the most characteristic; there is one fertile seed in each cell, with its longest diameter vertical and closely packed round with sterile seeds. In some species a membraneous prolongation of the testa is found to promote wind dissemination but this must have prevented ready exit of the seed from the fruit; this winged membrane is absent from the higher forms. With the introduction of emargination, the vertical diameter of the seed became greatly lessened, the seed broader and enlarged at one end, that in which the expanded lobes of the cotyledon lay; the folding of the halves of the cotyledons was vertical instead of transverse. This has been followed by a corresponding alteration of the fruits; the everted

rim has been done away with, though it sometimes recurs as an atavism, *e.g.*, in *E. urnigera*; the fruit is hemispherical or even broad and flat; this has led to the ovary rising higher and higher, so that in some species the valves when open in the dry state are very exserted. This has all tended to allow the ready and quick escape of the seeds from the fruit. These points are emphasised because I have found that in closely allied species, in which the fruits are very alike, we may also expect the cotyledons to be very much alike, not to exhibit marked specific difference, though slight ones can often be detected. In a many-species genus like that of Eucalyptus we are sure to find some factors, such as fruit, bark, &c., almost identically reduplicated; in such a case we certainly should consider all the factors such as buds, anthers, cotyledons, leaves, essential oils, &c., in the determination of the species.

Primary Leaves.—Almost all the Eucalypts possess the two types of foliage, the primary or juvenile and the secondary or adult. The term 'sucker leaves' should be entirely discarded. Study of the seedlings shows that the early leaves tend almost from the first pair to assume the form of the primary type; this type is always constant for the species. After a period of growth varying greatly in different species and even to some extent in individuals, the secondary type is adopted. The peltate form of leaf is generally the true primary type in the Corymbosa group. We see a persistence of this even in adult leaves in *E. peltata*, just as we see a similar occurrence in *E. cordata* and *E. pulverulenta*. The peltate leaves, as a rule, soon give place to the secondary type and so the fact of their occurrence has not been adequately recognised. The sessile or petiolate forms of the primary leaves are always constant and hence may be of importance in differentiating between two closely allied species; thus the petiolate leaves of *E. Andrewsi* distinguish it from the sessile ovate and cordate primary leaves of *E. dives*. The presence or absence of stellate hairs on the stem and primary leaves may also be of use in differentiation, as also the number and distribution of the oil-glands. This is interestingly borne out in the case of *E. fastigata* and *E. regnans*, which have been thought to be con-specific; but the seedlings are very noticeably different, that of *E. fastigata* having much smaller cotyledons, narrower lanceolate leaves of a finer texture and almost devoid of hairs; the oil-glands, even in the early leaves, are fairly plentiful, whilst they are almost absent from those of *E. regnans*. The cotyledons and primary leaves show that *E. regnans* belongs really to the 'Stringybark' group, as the cotyledons are entire and reniform and the primary leaves covered with stellate hairs. *E. fastigata* retains the stringy bark which *E. regnans* has lost more or less.

To sum up, Eucalypts defy all attempts to classify them according to any one character. A grouping according to barks does not agree with that according to essential oils, nor either of these with that according to cotyledons. Yet each is helpful in its own way in guiding us to a better idea of the true phylogeny of the genus. Both the cotyledons and primary leaves should be considered in differentiating species, as either may give valuable information. In the evolutionary



1a. Angophora lanceolata.
1b. Eucalyptus calophylla.
2. E. citriodora.
3. E. corymbosa.
4. E. lævopinea.
5. E. dumosa.
6. E. marginata.
7. E. Planchoniana.
8. E. acmenoides.
9. E. piperita.
10. E Luehmanniana.
11. E. amygdalina.
12. E. microcorys.
13. E. resinifera.
14. E. Stuartiana.
15. E. affinis.
16. E. rubida.
17. E. corynocalyx.
18. E. elæophora.
19. E. sp. nov.
20. E. gomphocephala.
21. E. cornuta.
22. E. calycogona.
23. E. pendula.
24. E. salubris.
25. E. squamosa.

A. Diagrammatic transverse section of seed of *E. corymbosa*: *t.* testa; *r.* radicle; C^1C^2 cotyledons.

B. Diagrammatic transverse section of seed of *E. globulus*: C^1C^1 halves of one cotyledon; C^2C^2 halves of the other.

C. Diagrammatic transverse section of seed of *E. squamosa*.

D. Diagram of reduction. The whole represents a cotyledon of *E. corymbosa*. Remove *a* for *E. Planchoniana*. Remove *a* and *b* for *E. elæophora*. Remove *a*, *b*, *c*, *d*, and *e*, for *E. squamosa*.

Illustrating the Report on the Botanical and Chemical Characters of the Eucalypts and their Correlation.

development of the genus there has been a reduction in size of the cotyledons, so that the tender germinating seedling may better cope with the dry conditions of Australia. This has taken place in some species by a simple reduction in size, in others by a reduction in size and the introduction of emargination. As the alteration in the cotyledons has taken place, a more or less corresponding change in the size and shape of the fruits has been effected. Lastly, the morphological characters of the cotyledons and primary leaves are constant in each species. The variation that takes place is more of the nature of a deviation or fluctuating variation.

The accompanying Plate VI. gives examples of Eucalyptus cotyledons—natural size.

Notes on the Evolution of the Genus Eucalyptus. *By* E. C. ANDREWS.

Résumé.—Eucalyptus is a highly specialised or secondary form of the primary or fleshy-fruited Myrtaceæ. The primary types are luxuriant and occur throughout the fertile tropics, whilst Eucalyptus and its allied genera are adaptations, in the main, to the more barren sandy and extra-tropical areas in Australia. Eucalyptus developed in warmer Australia and has never wandered beyond the neighbouring islands of that continent, except as a colonist.

Deane suggests (25) that the capsular-fruited Myrtaceæ originated in Northern or North-Eastern Australia; that these types attained their maximum development in Western Australia and gave rise to the fleshy-fruited Myrtaceæ, which spread later to Asia and Europe as differentiations of the primitive capsular type. Deane's idea apparently arose from the belief that capsular fruits had been developed before the fleshy forms. Even, however, if it be agreed that the capsular preceded the first baccate or drupaceous form of fruit, it does not at all follow that the capsular must precede the fleshy fruits in any particular family, especially such a relatively young one as the Myrtaceæ.

In connection with the position of the subject genus in its family it may be pointed out, in the first place, that the family Myrtaceæ consists of about 3,100 species, of which 2,500, approximately, occur in the fertile tropics or subtropics of the whole world. These include the vast genera Eugenia (1,325 species), Myrtus (200 species) and Myrcia (320 species); they are all of luxuriant habit, including some of the finest trees in the jungle. Eugenia and Myrtus are rich in species in America, Asia, Africa but occur more sparingly in Australia. All possess fleshy fruits, whereas Eucalyptus is a capsular form. Again, these fertile tropical types all possess leaves which are opposite and penniveined, dense, glossy and luxuriant in appearance. The anthers of all, moreover, are versatile, the cells parallel and opening longitudinally.

On the other hand, *Eucalyptus* possesses various forms of anthers; nevertheless, those of the section Corymbosæ or the 'Bloodwoods' exhibit the generalised type which is found in the tribe of the Myrtæ or the fleshy-fruited forms of the family. Moreover, it is just the

'Bloodwood' group which has been indicated as containing the earlier forms of Eucalyptus by reason of their oil-contents (7) by reason of the antheral classification of the genus by Bentham (26) and by their general appearance also, as shown by Cambage (1) and the writer (27).

In the second place, the genus Eucalyptus has all the biological signs of youth. It is vigorous and aggressive; it is rich in species; and it is the dominant vegetation of the continent of Australia. It occurs in every geographical situation; it swarms on the great sub-arid plains of the interior; it forms thickets on the barren sandstone; it survives the desolating winds of the colder plateaus; it flourishes in the ravines of the plateau margins; it grows in the swamps; and it advances almost to the very intersection of the planes of sea and land. As opportunity offers in other continents, it quickly establishes itself therein. Only in the jungle has it failed to establish itself. Were it a genus which had once been cosmopolitan, as asserted by Ettingshausen (28), now decadent, it would be represented by monotypic and oligotypic genera scattered in various isolated localities with wide stretches of intervening areas containing no representatives of the genus. On the other hand, it is not only overwhelmingly rich both in species and individuals in Australia but it is also excessively tenacious of life and adaptable to its environment. This suggests that it is a specialised form peculiar to Australia, much as the vast genus Myrcia is to tropical and subtropical America.

In the third place, the earlier life history of Eucalyptus suggests that it is a specialised form of the fleshy-fruited Myrtaceæ. Only in the juvenile forms of the genus are the leaves consistently opposite and penniveined, as in the fleshy pantropical forms In many species of the genus these generalised leaf types are obstinately persistent as in *E. cinerea*, *E. cordata*, and *E. pulverulenta* The obstinate persistence also of juvenile cordate, sessile, and horizontal leaves in the genus indicates that such leaf-types had been strongly established for a very long period in the family before the evolution of the genus Eucalyptus; and that the latter, typical Eucalyptus leaf, with twisted stalk, is an adaptation to a harsher climate and one which would tend to become extinct, in favour of the old persistent type, under certain favourable climatic conditions.

In the fourth place, the genus Eucalyptus appears to be a modification of a warmth-loving plant to meet varying conditions of dryness and coldness; as such it indicates a more youthful origin than that of the luxuriant and megathermic Myrtæ.

In the fifth place, the vast genera Eugenia and Myrtus have been enabled to occupy all the fertile tropics even in lands so widely isolated as Tropical America, Africa, Asia, and Australia. The morphology and habits of these luxuriant types suggest a former land connection between the great tropical lands. But these land bridges, if existent, do not appear to have been used by the genus Eucalyptus, and the only explanation possible, in view of the great vigour and tenacity of the genus, is that Eucalyptus was developed only after the separation of the great tropical lands from one another, whilst the Myrtæ were developed prior to such separation.

In the sixth place, it appears that the geography of Australia has changed considerably since the Cretaceous period. At that time Australia appears to have been occupied in part by a great central sea, surrounded by wide expanses of low-lying plains, mainly sandy in nature, the climate of the continent being mild and moist. That condition has now passed, the central sea has been drained, the old eastern plain has been uplifted to form high plateaus; these plateaus in turn have been covered in places with dense lava floods; the plateaus themselves have been worn away, in part, by streams and the material so worn has been distributed by the inland-flowing streams to form great alluvial plains, whilst the old moist and genial climate has been highly differentiated coincidently with these changes of topography. This suggests that the vegetation of Australia has been called upon to adapt itself to harsher conditions since the isolation of Australia. On the other hand, the great similarity to each other of the tropical Myrtæ suggests that Eugenia, Myrtus, and Myrcia developed under uniform and mild climatic conditions.

A consideration of these principles suggests that Eucalyptus was developed from the fleshy-fruited Myrtaceæ after the separation of the great tropical lands; that it was developed in warmer Australia, possibly the Northern or the more North-Eastern portion; that it was an adaptation in the first instance to the warmer sandstone areas and later either to drier climate or to heavier soils or to the colder localities.

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The Preparation of a List of Characteristic Fossils.—Report of the Committee, consisting of Professor P. F. KENDALL *(Chairman)*, Mr. W. LOWER CARTER *(Secretary)*, Mr. H. A. ALLEN, Professor W. S. BOULTON, Professor G. A. J. COLE, Dr. A. R. DWERRYHOUSE, Professors J. W. GREGORY, Sir T. H. HOLLAND, G. A. LEBOUR, *and* S. H. REYNOLDS, Mr. COSMO JOHNS, Dr. J. E. MARR, Dr. MARIE C. STOPES, Dr. A. VAUGHAN, Professor W. W. WATTS, Mr. H. WOODS, *and* Dr. A. SMITH WOODWARD, *appointed for the consideration thereof.*

DURING the year the Chairman has carefully considered the various suggestions sent in as the result of the preliminary list circulated by the Secretary. He has analysed the criticisms and suggestions and embodied them in a tabular form, which was submitted to the Committee. This showed that of 624 species included in the printed list 375 were accepted without any dissent. Of the 242 species challenged, 192 were objected to by only one or two critics. Of the 221 additional species proposed, 157 had the support of only one critic. Thus the general result seemed highly encouraging, and the Chairman recommended the appointment of a small sub-committee to deal with the lists and submit their contents to specialists, believing that in this way a list might be compiled that would meet with general acceptance.

The Committee met at Manchester on September 7 and received and adopted the Chairman's report. They modified this recommendation by appointing two Sub-Committees: (1) *Northern*—Prof. J. W. Gregory, Prof. P. F. Kendall, Prof. G. Lebour, and Dr. G. Hickling (convener); (2) *Southern*—Prof. W. S. Boulton, Dr. A. Vaughan, Mr. H. Woods, and Dr. W. T. Gordon (convener).

The Committee ask for reappointment with a grant of 10*l.* for printing in lieu of the same amount voted but not expended last year.

The Old Red Sandstone Rocks of Kiltorcan, Ireland.—Report of the Committee, consisting of Professor GRENVILLE COLE (*Chairman*), Professor T. JOHNSON (*Secretary*), Dr. J. W. EVANS, Dr. R. KIDSTON, *and* Dr. A. SMITH WOODWARD.

THE Committee has spent the sum of five pounds from the unexpended balance of the grant made in 1913, and has returned the remaining balance to the General Treasurer. The grant of 10*l.* made in 1914 was not called on, since the work for which it was specially intended, excavation at Tallow Bridge, proved impracticable, owing to local difficulties. The regular working of the Kiltorcan quarry, however, makes it desirable to secure good specimens as they are turned out, since the owner is the local contractor for roads, and the stone and plant-remains become alike used in making the Kilkenny highways. Short of actual purchase and preservation of the historic site, the alternative is to pay the owner to watch the work as it goes on and to set aside the more interesting material. He has shown a ready appreciation of the requirements of the Committee.

Hence the Committee asks for its continuance and a grant of ten pounds for the excavation-work at Kiltorcan, and for specimens obtainable in 1915-1916.

The Committee would be glad to be allowed to send, carriage forward, duplicate material of *Archæopteris*, *Bothrodendron*, *Archanodon*, &c., to the botanical and geological sections of universities, colleges, and museums in the British Empire, where it is found that such specimens would be welcome. Such gifts would, of course, be accompanied by a statement as to the auspices under which the material was obtained.

The Lower Palæozoic Rocks of England and Wales.—Report of the Committee, consisting of Professor W. W. WATTS (*Chairman*), Professor W. G. FEARNSIDES (*Secretary*), Professors W. S. BOULTON *and* C. LAPWORTH, Mr. E. S. COBBOLD, Mr. V. C. ILLING, *and* Dr. J. E. MARR, *appointed to excavate Critical Sections therein.*

OWING to the early departure of the Association for Australia in 1914 it was not possible to report on the work of the preceding year in Shropshire. The annexed report gives an account of Mr. Cobbold's excavations in that and the previous year

The war has rendered it impossible to carry out any excavations during 1915.

The Committee asks for reappointment, with a grant of 15*l.*—this year's unexpended grant.

Sixth Report on Excavations among the Cambrian Rocks of Comley, Shropshire (1912, 1913, 1914). *By* E. S. COBBOLD. *F.G.S.*

A portion of the grant made to the Committee on its reconstitution at the Birmingham Meeting was entrusted to the writer for the continuation of his excavations in the Comley area.

In the previous year, when no grant was available, certain sections

were opened out in the subsidiary area called the Cwms (about two miles south-west of Comley itself) with funds from another source, and a summary of the results appeared in the Report of the Birmingham Meeting.[1]

Additional work has now been done at these sections with the help of the grant made in 1913, and full details are incorporated in the present Report.

A. Excavations in the Cwms.

Excavation No. 53.—The Road Quarry.

This little quarry had been cleared of débris and was subsequently deepened at certain points. The complete section thus exposed was as follows in descending order:—

North-East End of the Section.

	ft.	in.
d. 'The Greenish-grey Sandstone.'		
d_3. Hard quartzose sandstone	1	6
d_2. Do., do., with large ovoid and elongate cavities and masses of rotten-stone up to 10 cm. in diameter; these are almost certainly of organic origin, but their nature has not as yet been determined. *Hyolithellus* sp. *Hyolithus* cf. *H. primævus*, Groom, *Obolella* ? *groomi*, Matley, *Micromitra* spp., and another brachiopod allied to both *Mickwitzia* and *Kutorgina*.	1	3
d_2. Hard quartzose sandstone	3	0
d_1. Well-bedded sandstones, rather soft and less quartzose than d_2	15	0
c. Shale with thin bands of quartzite	2	0
Fault.		
b. 'The Mottled Beds' (about 4 feet seen).		
b_3. Conglomeratic quartz grit, with well-rounded grains and pebbles of quartz, a small amount of glauconite, and a few pebbles of felsitic rocks	1	4
b_2. Yellowish quartz sandstone, mottled with brown streaks and patches of dark rotten-stone and having a thin layer of quartzite at the base	1	6
b_1. Conglomerate with many sub-angular pebbles of mudstone, pink and buff-coloured felsitic rocks, and brown quartzite; also containing rounded or elongate masses of rotten-stone, suggestive of the former presence of calcareous organisms	1	4
Fossils from the two beds b_1 and b_3. *Hyolithellus*, sp. *Hyolithus* sp. *Obolella groomii*, Matley. *Micromitra* spp., and two other brachiopods, allied to both *Mickwitzia* and *Kutorgina*.		
a. 'Wrekin Quartzite,' about 16 feet seen.		
a_8. Yellowish quartzose sandstone, nearly a quartzite	1	6
a_7. Pale blue compact quartzite, with occasional pink grains of felsite	2	0
a_6. Yellowish quartzite, with well-marked compact blue and impure yellow bands	2	0
a_5. Impure yellowish quartzite, much fractured	0	8
a_4. Compact blue quartzite	0	8
a_3. Compact blue quartzite	1	0
a_2. Mottled blue and yellow compact quartzite	4	0
a_1. Compact quartzite, bedding disturbed	4	0
Broken blocks of quartzite, occupying a distance equivalent to a further thickness of about	6	0

Probable Fault.

South-West End of the Section.

The dip of the beds throughout remains fairly constant at about 80° N., 70° E.

[1] *Rep. Brit. Assoc.* 1913, Birmingham (1914), p. 486.

The broken condition of the quartzite at the southern end of the section is probably due to the proximity of a strong longitudinal (N.E. and S.W.) fault ('The Road Fault,' Lapworth), which separates the Uriconian of Caradoc Hill from the Cambrian and Ordovician rocks of the Cwms.

The fault in the section itself is one of the minor fractures, transverse to the major faults which determine the orographic features of the district.

The fossils from the Mottled beds and Greenish-grey sandstone are of considerable interest as representing the oldest-known fauna of the district, and may be compared with those collected by Dr. Groom from the Quartzite and Hollybush Sandstone of the Malvern area.

The gradation, by intercalation, from quartzite below to sandstone above, and the occurrence of the conglomeratic beds, confirm and supplement the observations made on Excavation No. 4[2] at the north spur of Little Caradoc, Comley.

Excavation No. 54.—*The Middle Ridge in the Cwms, about* 150 *yards South of No.* 53.

A trench was cut across a knoll where some hard grit protruded, and a short summary of the section obtained was published in the report of the Birmingham Meeting. The section confirms and supplements those of the Quarry Ridge at Comley.[3] The complete section is as follows :—

Eastern End of the Section.

	ft.	in.
MIDDLE CAMBRIAN.		
e. Shale, with bands of hard glauconitic grit. *Cf.* The Quarry Ridge Shale.		
e_3. Clay with fragments of shale.		
e_2. Band of hard, ringing, glauconitic grit	1	6
e_1. Brownish shale crushed and fractured	2	0
d. Hard, ringing, glauconitic grit in beds from 3 to 24 inches thick. *Cf.* The Quarry Ridge Grit	28	0
c. Conglomerate, *cf.* The Quarry Ridge Conglomerate.		
c_4. Brown pebbly somewhat incoherent grit, with small felsitic and quartz pebbles, and a few rounded fragments of Lower Cambrian Limestones	1	0
c_3. Coarse conglomerate, incoherent and usually dark in colour, with many subangular blocks of Lower Cambrian Limestones, among which are fragments of the granular portion of the Black Limestone.		
c_2. Dark rotten-stone, chiefly consisting of grains of quartz and glauconite *Acrothele* sp., *Acrothyra* sp., *Hyolithellus* and many fragments of Trilobites.	1	0
c_1. Black skin of phosphatic material, partly adherent to the next bed below and partly invading the grit above, thickness variable up to	0	2
LOWER CAMBRIAN.		
b. Black, Grey, and *Olenellus* Limestones.		
b_5. Black Limestone, granular and phosphatic	0	4
b_4. Black Limestone, compact and crowded with fragments of Trilobites. *Protolenus* sp., *Callavia* sp.	0	6
b_3. Dark purple compact Limestone. weathering to a yellowish clay; trilobite fragments plentiful	0	6
b_2. Dark purple compact sandy Limestone with abundant minute mica flakes	1	0
Callavia callavei Lapworth (?). *Anomocare pustulatum* Cobbold, *Microdiscus attleborensis* S. & F., *Obolella, Micromitra labradorica, M.* sp. and *Ostracoda.*		

[2] *Rep. Brit. Assoc.* 1908, Dublin (1909), p. 238.

[3] *Rep. Brit. Assoc.* 1908, Dublin (1909). Excavations Nos. 1 and 2, pp. 234, 236.

	ft.	in.
b_1. Red, sandy and micaceous Limestone in nodules; trilobite fragments very plentiful	1	0
a. Lower Comley Sandstone.		
a_3. Mottled red and green micaceous sandstone, soft and somewhat fissile above, harder and more compact below	4	0
a_2. Green micaceous sandstone with rusty spots, and one specimen of *Hyolithellus*	0	6
a_1. Green micaceous sandstone; base not seen	6	0

Western End of the Section.

The dip of the beds throughout is 80°, N.75° E.

This section is now filled in. It repeats in all its main features the sequence shown in the Quarry Ridge[4] of Comley, which is about one and a half miles away. It is noteworthy that the dividing line between the Taconian and Paradoxidian (=the plane of erosion) lies at exactly the same horizon (the top of the Black Limestone) in the two places, though at Robin's Tump, which is about half-way between them, the Taconian strata are seen to have been eroded to a much lower level.[5] In a few particulars the section now being dealt with supplements the information given by Excavations Nos. 1 and 2.

(i) The Conglomerate (c) has here a distinctly sandy bed at the top (c_4) and another at the base (c_2), indicating that it is complete and not affected by the strike faulting, so prevalent in the Quarry Ridge of Comley.

(ii) This Conglomerate contains many angular blocks of Black Limestone of both the granular and the compact varieties (beds b_5 and b_4 of the section) which had not been noted from the Conglomerate at Comley. There are also, as at Comley, numerous blocks of the Grey and *Olenellus* Limestones. It is now clear that all the Limestone bands were subject to erosion at the time when the Conglomerate was formed.

(iii) The black skin (c_1) at the base of the Conglomerate has its counterpart at Comley in a similar black deposit, which contains *Paradoxides*, *Dorypyge*, and a species referred to *Acrothyra*. The same species of *Acrothyra* is found in the sandy bed c_2, but the Trilobites in that bed have not been identified.

(iv) In the Cwms section the compact or lower portion (b_1) of the Black Limestone is crowded with fragments of Trilobites, many of which have the reticulate surface characters of *Olenellus* or some other genus of the Mesonacidæ. This necessitated a further study of Excavation No. 2 at Comley (see following page).

Excavation No. 55.—The Cwms Brook.

The Lower and Middle Cambrian rocks are naturally exposed in the bed of this stream for about 300 yards to the southward. The section across the junction was opened out and the contact was proved to be a faulted one, the whole of the Limestones of the lower series being cut out at this point.

Excavation No. 56.—The Lower Ridge in the Cwms.

A few small trials were made where the Quartzite composing the ridge outcrops, but no continuous section could be observed, without undue disturbance of the cultivated ground. The presence of greenish-grey and mottled sandstone lying above the quartzite was noted.

[4] *Op. jam cit.*

[5] *Rep. Brit. Assoc.* 1911, Portsmouth, 1912, pp. 112, 113, and figs. 1, 2, and 3.

B. Excavations in the Comley Area.

Excavation No. 2.—200 Yards South of Comley Quarry, Reopened.

The discovery of fragments of *Olenellus, sensu lato* in the Black Limestone of the Cwms (see above), rendered additional work advisable at the same horizon in the Quarry Ridge at Comley, the full section of which is given (*op. cit.*) in the report to the Dublin Meeting.

The Black Limestone was uncovered and some highly fossiliferous blocks obtained; these yielded at least two species of trilobites referable to the *Mesonacidæ*; fragments provisionally referred to *Oryctocephalus*, which is a genus found in both Middle and Lower Cambrian of America; a species of *Microdiscus* that appears to be undescribed; and a number of specimens of *Hyolithidæ*. All of these require critical study before they can be specifically determined.

Excavation No. 4.—North spur of Little Caradoc, 200 yards west-south-west of the Comley Quarry, reopened.[6]

The old trench was considerably widened and deepened at the site of the beds marked a_2 in the Dublin Report, to which the Mottled Beds (*b*) of the section of the Road Quarry (see above) bear a strong lithological resemblance. The grits with rounded quartz grains were found to contain pebbles of pre-existing rocks and also fragments of *Brachiopoda*, some of which are referred to *Obolella* (?) *groomii* and a species of *Micromitra*.

Excavation No. 5.—Hill House Ridge. North End[7]

Here further work in quarrying rough stone for walling had been done by the occupier of the land, and from the material of the Hill House Grits thus exposed a single cranidium of *Paradoxides intermedius* Cobbold was obtained. Fossils that can be identified are very scarce in these beds.

P. intermedius occurs typically in the Comley Breccia Bed.[8] The Hill House Grits may therefore be regarded as belonging to the same faunal horizon as the Breccia Bed, which has been proved to be equivalent to some part of the Swedish *P. tessini* zone.

Excavation No. 57.—Caradoc Dingle.

In a little wooded hollow called Caradoc Dingle about half-way between the Comley Quarry and Robin's Tump soft shales are exposed at one or two places in the bed of the brook. At one point a rib of rock some eight or ten yards long projects through the soil, and from it in 1901 a few brachiopods were found on the occasion of an excursion of the Liverpool Geological Society. A trench was cut across this rib and the following section was exposed:

West End of the Section.

		ft.	in.
b_2.	Bluish shale, much crushed and fractured, about 3 feet seen. (Brachiopoda were obtained from this bed by Prof. Lapworth and Mr. Rhodes in 1892 or earlier.)		
	Interval where no rock is seen of about	12	0
b_1.	Shale rather harder but much crushed	8	0
a_3.	Band of pyritous grit	0	2

[6] *Rep. Brit. Assoc.* 1908, Dublin, 1909, p. 238.

[7] *Rep. Brit. Assoc.* 1908, Dublin, 1909, p. 240.

[8] *Rep. Brit. Assoc.* 1912, Dundee, 1913, pp. 139, 140, and *Q.J.G.S.* vol. lxix. 1913, pp. 27–44.

Billingsella lindstrœmi var. *salopiensis* Matley very plentiful, *Acrothele coriacea* Linnarsson, *Acrotreta*, cf. *sagittalis* Salter, *A. Schmalenseei* Walcott, *Obolus* (?) sp. index Linnarsson (1876).

		ft.	in.
a_4.	Shale with sandy bands	3	0
a_3.	Hard, micaceous, and siliceous grit	0	6
a_2.	Flaggy, micaceous shale	2	0
a_1.	Hard, flaggy, siliceous and micaceous grit	1	0
	Shaly material	3	0

East End of the Section.

The shale and bands of grit of this section have a very strong resemblance to those of Excavation No. 21, the lower section on the Shoot Rough Road, and the *Billingsella* occurs in the same state of preservation and in the same profusion. The only differences observed in the section are: (1) the comparative thinness of this bed, and (2) the absence of rottenstone bands (representing calcareous bands) above the *Billingsella* grit in this new section in Caradoc Dingle.

The shales, *b*, are consequently regarded as equivalent to the Shoot Rough Road shales (the *Orusia lenticularis* horizon) and the flaggy beds, *a*, as equivalent to the upper portion of the Shoot Rough Road Flags. All the fossils identified from the *Billingsella*-band a_5 are found in Scandinavia in the *Paradoxides forchammeri* zone.

Excavation No. 58.—*South-west Slope of Little Caradoc*

In the hope of finding sections comparable with those of Excavations Nos. 4 and 53, some preliminary trial-holes (3 feet or more long and about the same depth) were made where the Quartzite crops out in the little gully between the Caer Caradoc Hill and Little Caradoc. These showed that the ground here is intensely faulted and that no continuous section is to be hoped for. Quartzite, flaggy beds, and green sandstones occur in the various trial-holes without any orderly arrangement being apparent. The surfaces of the flaggy beds in one place showed tracks of organisms, similar to those found in Excavation No. 41, south-west of Hill House,[9] but there was no evidence to show whether the beds should be regarded as within the Quartzite sequence or as belonging to the Lower Comley Sandstone.

Excavation No. 59.—*In Comley Brook about* 50 *Yards North of the Shoot Rough Road.*

A rib of mudstone crossing the bed of the Comley Brook, from which fossils were collected by Mr. Manson, of H.M. Geological Survey, during the summer of 1914, has been laid bare by excavation, and the following forms obtained:—

Orusia lenticularis Wahlenberg sp.
Acrothele ? fragments.
Trilobite fragments.

The mudstone occurs as a band about 12 inches thick in shales referred provisionally to the Shoot Rough Road shales. The strike is approximately north-east and south-west, and the dip vertical. The Trilobite fragments are not sufficiently complete for exact determination, but may be said to be reminiscent of *Olenus, sensu lato*. A block or nodule of similar rock, with the *Orusia* very well preserved, was found some

[9] *Rep. Brit. Assoc.* 1911, Portsmouth (1912), p. 113.

years ago on the surface of the shale [10] in the old roadway near Excavation No. 24, some 250 yards to the east of the present exposure.

Summary of Results.

The Excavations detailed in this Report have proved:—

(1) The existence of a section in the Cwms (No. 54), which is entirely confirmatory of those of the Quarry Ridge (Nos. 1 and 2).
(2) The presence of *Olenellus, sensu lato*, in the Black Limestone, which bed may now be definitely assigned to the Lower Cambrian.
(3) The presence in the lowest known portion of the Lower Cambrian Sandstone (the Mottled and Greenish-grey sandstones) of a fauna comparable with that of the Hollybush Sandstone of Malvern.
(4) The presence in the Hill House Grits of *Paradoxides intermedius* Cobbold as well as that of *Ptychoparia* (*Liostracus*), sp. cf. *lata* Cobbold, previously known, which two species are found together in the Comley Breccia bed.

The inference from (4) is that the two deposits denominated the Breccia bed and the Hill House Grit are of the same age, though one of them (the Breccia bed) rests directly upon the Lower Comley Sandstone, while the other (the Hill House Grit) is separated from that Formation by about 300 feet of Shales, Grits, and Conglomerate (the Quarry Ridge Shale and Grit of the Dublin and subsequent Reports).

The principal Results of previous observations were summarised in the Report to the Dundee Meeting.[11]

The writer desires to take this opportunity of acknowledging very gratefully the assistance he has received from the Association in enabling him to explore the Comley Section so much more fully than would have been possible without excavation, and thus to establish a considerable number of life zones in the Shropshire Cambrian Rocks. He is also greatly indebted to Professor Lapworth for advice and other help throughout the whole course of this investigation, and to Dr. Matley, Mr. Philip Lake, Professor Groom and others for aid with the Palæontology.

Stratigraphical Names.—Interim Report of the Committee, consisting of Dr. J. E. MARR (*Chairman*), Dr. F. A. BATHER (*Secretary*), Professor GRENVILLE COLE, Mr. BERNARD HOBSON, Dr. J. HORNE, Professor LEBOUR, Dr. A. STRAHAN, *and* Professor W. W. WATTS, *appointed to consider the preparation of a List of Stratigraphical Names used in the British Isles, in connection with the Lexicon of Stratigraphical Names in course of preparation by the International Geological Congress.*

IN consequence of the war, it has not been possible for the Secretary of this Committee to communicate further with the Secretary of the Committee appointed by the International Geological Congress. It is, therefore, impossible for the present to draw up a plan of operations.

The same reason rendered it inappropriate to act on the suggestion

[10] *Rep. Brit. Assoc.* 1909, Winnipeg (1910), p. 186, and footnote.
[11] *Rep. Brit. Assoc.* 1912, Dundee (1913), p. 142.

made in the last Report of the Committee that a similar committee should be appointed for Australasia.

In order that it may be in a position to resume operations when international relations are restored to the normal, your Committee asks for its reappointment, but for the present without a grant.

Belmullet Whaling Station.—Report of the Committee, consisting of Dr. A. E. SHIPLEY (*Chairman*), Professor J. STANLEY GARDINER (*Secretary*), Professor W. A. HERDMAN, Rev. W. SPOTSWOOD GREEN, Mr. E. S. GOODRICH, Professor H. W. MARETT TIMS, *and* Mr. R. M. BARRINGTON, *appointed to investigate the Biological Problems incidental to the Belmullet Whaling Station.*

THE Committee arranged with Mr. J. Erik Hamilton for the further prosecution of their researches in 1914. He proceeded to Belmullet on May 24, but received mobilisation orders early in August. The Committee sympathise with Mr. Hamilton in that owing to ill-health he was subsequently discharged as medically unfit. Mr. Hamilton's report is appended.

The Committee regret that both of the Belmullet fisheries, Blacksod Bay and Inishkea, are at present suspended. Inquiries were made as to other northern fisheries, as the Committee proposed to ask permission of the Council to send Mr. Hamilton, who is anxious to continue his work, to one of these. They too are closed. The grant for the present year has consequently lapsed. The Committee ask that it shall be regranted for 1916, and that they shall be empowered to substitute another station in the North Atlantic in 1916 if the Belmullet stations are still closed.

Report by J. ERIK HAMILTON, *M.Sc.*

I. *Introduction.*

On May 23, 1914, I proceeded to Blacksod Bay to continue the investigations on whaling in which I had been engaged the previous year.

The 1914 season was successful, in spite of the fact that the use of three steamers instead of two, as in former years, made it necessary for financial success to secure a correspondingly larger number of whales. Eighty-six whales were taken, which yielded over three thousand barrels of oil.

The whaling station formerly at Inishkea did not open in 1914. The plant has been removed to the Spanish coast of the Mediterranean for winter fishing. It is expected that Fin Whales will form the bulk of the catch.

During this season I had an opportunity of tasting the flesh of *B. borealis*, which is to my mind inferior to that of *B. musculus* (Blue Whale), although the Norwegians consider it to be the more palatable. The Scandinavian hands at the station salted down a great part of the flesh of the solitary example of this whale which I saw. One specimen of *B. physalus* (Finner) was lactating very freely, and as it was recently killed I tasted the milk, which is in colour dead-white,

and appears to be very rich in fat. The flavour resembles that of rich cream, the oily taste which it possesses not being very noticeable.

On board one of the steamers I found a harpoon which differed considerably from those which I had seen before. This projectile has a rigid shaft, being devoid of the link joint which is present in the ordinary harpoon. There are no barbs. At the anterior end the shaft swells gradually from its normal diameter to a thickness corresponding to the diameter of the base of the cast-iron explosive point. There are the usual arrangements for fitting on the point and for attaching the time fuse. This instrument is called a 'killer,' and is used for giving the *coup de grâce* to wounded whales when the stock of ordinary harpoons on board the steamer is becoming exhausted.

Since there are no barbs; the killer may be readily withdrawn from

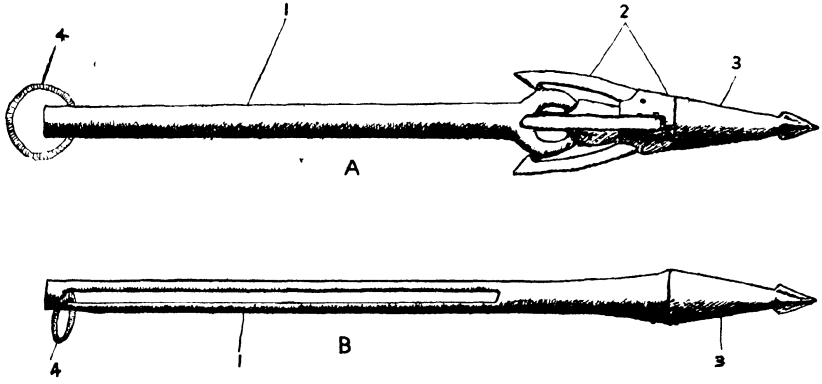


FIG. 1.—A. Ordinary Harpoon. B. 'Killer.'

1. Wrought-iron shaft, with slot, not visible in A, for wire ring to which the rope is attached. 2. Steel head, with four hinged barbs. 3. Cast-iron explosive point. 4. Wire ring.

the body of the animal into which it has been fired, after the point has exploded. When a new point has been fixed the harpoon may be again used for a similar purpose.

The accompanying sketch shows the two forms of harpoon in use (Fig. 1).

I wish very heartily to thank the British Association's Committee for again giving me an opportunity of working on this interesting subject.

To my friends Mr. D. Bingham and Captain Lorens Brunn my best thanks are due for ever willing assistance and information. I am also much indebted to Professor W. A. Herdman, F.R.S., and Professor J. Stanley Gardiner, F.R.S., for much kind advice and aid, and to Mr. D. G. Lillie for his communication on the nomenclature of the Whalebone Whales.

I have pleasure in again recording the willing help given to me on many occasions by all hands at the station, both Scandinavian and Irish.

The work of examining the material in detail was carried out in the Zoological Laboratory of King's College, London.

II. *Nomenclature.*

I am indebted to Mr. D. G. Lillie for drawing my attention to the claims for precedence of the nomenclature which True has worked out. The latter has published his authority for its use in the 'Proceedings of the United States Natural History Museum.'[1]

The following extract from True was made by Mr. Lillie:

'*Balæna musculus.*

'Linnæus' description vague. He refers to two other authors who refer to Sibbald's description of what is pretty certainly the "Blue Whale." Hence Linnæus must have meant *Balæna musculus* to denote the "Blue Whale." Hence (the Blue Whale is) *Balænoptera musculus* Linn.

'*Balæna physalus.*

'Linnæus' description vague. But he refers to Martins, whose account pretty certainly refers to the Common Rorqual. Hence *Balænoptera physalus* for this whale.

'*Balæna boops.*

'Linnæus refers to Sibbald's description of what is very evidently an immature specimen of the Common Rorqual and (this name) is hence synonymous with *Balæna physalus.*

'*Megaptera nodosa* Bonnaterre.

'The American Humpbacks were named before the European ones, so the names *Balæna boops* Fabricius, 1780, and *Balæna nodosa* Bonnaterre take precedence of *Balæna longimana* Rudolphi, 1829.

'But *Balæna boops* has been used by Linnæus as a synonym for *Balæna physalus*, therefore *Megaptera nodosa* should hold the field on priority grounds.'

In accordance with the above, I have adopted True's nomenclature throughout this Report. I therefore append a table giving this nomenclature with the synonyms which have been used by Burfield[2] and myself[3] in previous reports:

B.A. Reports 1912 *and* 1914.		*True.*
Balænoptera musculus L. Common Rorqual, Fin Whale.	=	*Balænoptera physalus* L.
Balænoptera sibbaldii Gray Blue Whale.	=	*Balænoptera musculus* L.
Megaptera longimana Rudolphi Humpback	=	*Megaptera nodosa* Bonnaterre.

III. *Numbers and Species taken in* 1914.

The total number of whales captured in 1914 was eighty-six, and included four species. The relative numbers were as follow:

Fin Whales (*B. physalus* L.)	67
Blue Whales (*B. musculus* L.)	13
Sejhvals (*B. borealis* Lesson)	2
Sperm Whales (*Ph. macrocephalus* L.)	4
Total	86

[1] 'On the Nomenclature of the Whalebone Whales of the 10th ed. *Linn. Syst. Nat.*,' *op. cit.* vol. xxi. p. 617, 1898.

[2] *British Association Report* 1912, 'Report on Belmullet Whaling Station.'

[3] *British Association Report* 1914, 'Report on Belmullet Whaling Station.'

Of the above I had the opportunity of examining thirty-six specimens—Fin Whales 31, Blue Whales 4, Sejhval 1.

A mass of ambergris of fifteen pounds' weight was obtained from one of the Sperm Whales.

IV. *Measurements and Proportions.*

(See Tables at end of this Report.)

The series of measurements used last year [4] was retained, and in addition one other dimension was added. I have used the name 'falcation of dorsal fin' for this measurement. If a line be taken from the tip of the dorsal fin to the line of the back, and at right angles to the long axis of the animal, the maximum distance from this line to the posterior margin of the dorsal fin is the 'falcation of the dorsal fin.'

It indicates the depth of the notch in the posterior margin of the dorsal fin, and is very varied. The maximum is 11 in. = 4·1 per cent., and the minimum 4 in. = ·49 per cent. So far as can be seen from

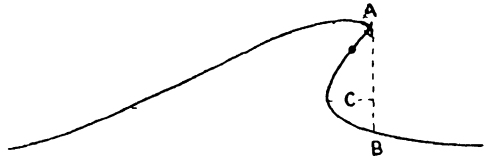


FIG. 2.—Dorsal fin. *B. physalus*, showing new measurement, indicated by line C.

so small a number of specimens (27) the variation is not dependent on sex. In fig. 2 the line C indicates new measurement.

In No. 22, a Fin Whale, one fluke had not been completely severed, and I was therefore able to measure it. The distance between the tip of the fluke and the notch between the flukes, measured along the posterior margin, was 7 ft. 4 in., giving a spread of 14 ft. 8 in. for the flukes.[5]

Total Length.

The accompanying tables give the averages of total length of the species seen and a more detailed analysis of the total length of the Finners.

Finners (*B. physalus* L.).

		Ft.	in.
Average length of all Finners	(31)	59	11
,, ,, ,, females	(16)	63	5
,, ,, ,, males	(15)	56	2
,, ,, ,, adult females	(13)	66	2
,, ,, ,, ,, males	(9)	60	1⅞
Maximum for females		70	9
Minimum ,, ,,		49	4
Maximum ,, males		64	10
Minimum ,, ,,		44	6

[4] *British Association Report* 1914, p. 128.

[5] *Cf. British Association Report* 1914, p. 129.

Comparing these results with those of 1913:

	1913.[6] Ft.	in.		1914. Ft.	in.
Average for all specimens (37) . . .	59	3	(31)	59	11
,, ,, females (17) . . .	60	7	(16)	63	5
,, ,, males (20) . . .	59	0	(15)	56	2
,, for adult females (12) . . .	64	0	(13)	66	2
,, ,, ,, males (16) . . .	60	8	(9)	60	0½
Maximum for females	69	8		70	9
Minimum ,, ,, ...	66	0		64	10
Maximum ,, males	48	7		49	4
Minimum ,, ,, ...	46	7		44	6

It is worthy of note that not only is the general average for 1914 slightly greater than that for the preceding year, but the average size of all females and of adult females is markedly larger than the corresponding dimensions for 1913.

With regard to the males, the average for all males, the maximum and the minimum are all markedly less, while the average for adult males, although less, does not fall very far below the measurement for 1913.

In 1914 the percentage of adult females was 81.25 (13 : 16), and in 1913 it was much lower, 70·59 (12 : 17), while in 1911 it was 95·24 (20 : 21). Although the earliest figure (1911) is also the largest, the fact that the latest figure is larger than that preceding it emphasises the importance of having a good series of figures before a reliable statement can be made on the subject of extermination.

In regard to the males, the averages for all males and for adult males are less for 1914 than for 1913 The percentages are 1914, 60 (9 : 15); 1913, 80 (16 : 20), showing a consistent diminution, since the percentage for 1911 is 92 (23 : 22).

Blue Whales (*B. musculus* L.).

Of the thirteen Blue Whales of the 1914 season I examined four (see Table II. at end of this Report).

The other Blue Whales were taken between July 1 and July 14, during my absence in Liverpool, and also after I left Blacksod on August 2.

Comparing with the figures for 1913:

	1913. Ft.	in.		1914. Ft.	in.
Average for all females (4)	71	3¾	(4)	66	8½
Maximum for ,, ...	78	2		73	1
Minimum for ,, ...	68	0		61	9

A diminution in average size and also in individual measurements is noticeable. None were pregnant.

Sejhval (*B. borealis* Lesson).

Only one specimen of this whale was brought in during my stay.

	Ft.	in.
Female	39	0

[6] *British Association Report* 1914, p. 129

Sperm Whales (*P. macrocephalus* L.).

The four examples brought in this year were all taken after I had left Blacksod.

V. *General Observations.*

(1) *B. physalus* L.

(*a*) *Coloration.*—I managed to obtain some idea of the colour distribution on the dorsal surface. I believe that the general pattern, if it may so be termed, is not the result of individual peculiarity, but characteristic of the species. It is only in the most recently killed specimens that any accurate observations can be made, as exposure to light and decomposition blacken the dorsal surface. The latter agent also destroys the skin by the formation beneath it of bubbles, which generally contain fluid much discoloured by blood.

Figure 3 is from a sketch made partly from a photograph and partly

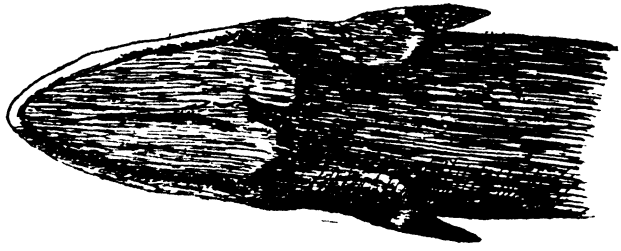


FIG. 3.—*B. physalus.* Dorsal surface, showing colour markings. 1 inch = 12 feet approximately.

from sketches made on the flensing plane. The actual tint of the pigmented parts of the whales is a *pale* leaden grey, not nearly approaching black, which varies in depth in the manner shown. It is noteworthy that the pale area of the upper surface of the rostrum is asymmetrical. It extends, behind the blowholes, almost to the middle line from the right, whereas on the left it falls short of doing so by a noticeable distance. The pale area behind the eye extends some distance down the pectoral fin, and the somewhat lighter, narrow line which divides it from the darker colour of the dorsal surface is continued across the limb to the anterior margin of the same.

(*b*) *Scars.*—As has been noticed in other years, scars of various sorts are not infrequently observed. Some of these take the form of long scratches which might be caused by the whale cutting itself on rocks when diving in shallow water. On whale 14 ♂, there was an unhealed wound on the right side of the tail, about 20 in. from the anterior margin of the fluke. It was oval in shape, and about 2½ in. long by about 1¾ in. broad. The right flipper of whale No. 19 had been broken off at some time during the animal's life. The stump was only 3 ft. 8 in. long, and partly healed over.

I was informed by one of the Norwegians that he had frequently seen whales which had a flipper damaged in this manner.

(*c*) *Flukes.*—The flukes of the Fin Whale frequently overlap in the middle line. The posterior margin of each fluke forms a rounded lobe as it approaches the middle line, and to the presence of these lobes the formation of the caudal notch is due. In some cases the notch is open, *i.e.*, the flukes do not overlap, and in any case the lobes never fuse.

From the examination of eighteen whales the following result was obtained:

Notch open	6
Left fluke uppermost	8
Right „ „	4

In the Blue Whales numbers 1 and 3, and in the Sejhval the notch was open.

(2) *Sejhval* (*B. borealis* Lesson).

As in 1914, the only specimen seen was a female. A number of white patches, which appeared to be healed cuts, were observed on the right side of this animal. They were about 2½ in. long and ¾ in. wide. There were 306 plates of baleen on the left side of the mouth.

VI. *Food.*

In only one case was any trace of food other than 'Krill' found in the stomach of any species. The exception was No. 28, a Finner, in the rectum of which a number of small fish otoliths were found; they were about ¼ in. long. The presence of these can scarcely be regarded as evidence that the whale had been feeding on fish, since small fish might very easily have been taken in if they were mingled with the 'Krill.'

VII. *Notes on Miscellaneous Specimens Preserved.*

(*a*) Under this heading a cyst was described in the Report for 1913.[7] During the 1914 season similar objects were met with, but as they appear to be precisely similar it is not necessary to describe them.

(*b*) On the exterior of the stomach of No. 28 Finner, ♀, four spherical, soft bodies were found. They were loosely attached to the wall of the organ, and are about 1⅛ in. in diameter. In section a fairly thick fibrous capsule is visible, while bands or sheets of the same material run through the mass of the specimen. The considerable intervening spaces are partly empty in the preserved specimen and partly filled with material of a uniform consistency. This appears to have been partly cellular, and in it here and there small rounded objects are visible. They stain uniformly with borax carmine, or the stainable material takes the form of a collection of minute dots of varying size.

It may be suggested that these darkly staining masses denote the presence of some Protozoan parasite. But I find on reference to my diary that Whale No. 28 is described as 'very rotten.' It is therefore obvious that no histological detail can be made out with any certainty.

[7] *British Association Report*, p. 138 (*a*), 1914.

In the fresh condition the cysts were white on the exterior, but had dark-red contents.

(*c*) In No. 11, Finner, female, I found in the uterus a vesicle $1\frac{3}{4}$ in. in diameter and filled with a clear yellowish fluid. This was preserved in the hope that it might be an early embryonic stage, but on examination no trace of an embryo could be discerned.

In section the walls of one vesicle show uterine glands, and blood-vessels, in connective tissue. I believe this to be one of the 'ovulæ Nabothi' of the human anatomists. These are visible to the naked eye in the human uterus, and it seems not unreasonable to expect that in an animal so much larger, such as a whale, the 'ovulæ' would be of correspondingly greater size. This was the largest vesicle seen, but a number of smaller vesicles were observed. A number of small roundish objects about $\frac{1}{8}$ in. long, and which proved to be masses of cells, were found in the same uterus. They may have been wandering leucocytes, which had passed through the uterine wall into the lumen of the organ.

VIII. *Parasites.*

1. *External.*

(*a*) *Balænophilus unisetus* (Aurivillius).—There is nothing new to report on this form.

(*b*) *Penella* (Kov. and Dan.).—A few specimens were found, all females. No males were observed on them. One, seen on June 27, had egg-sacs of great length.

2. *Internal.*

(*a*) *Monostomum plicatum* (*Creplin*) was found in the intestines of fourteen of the Fin Whales examined. One specimen of exceptional size was taken. It is 1·7 cm. in length (in a somewhat compressed condition).

(*b*) *Cestodes.*—(i) In the intestine of Finner No. 9 a number of cestodes were found. They were plentiful, nine being taken from about a yard of gut. These parasites are of small size, about 8 in. long. The scolex is dilated and has four well-marked suckers, but there appears to be no armed rostellum. The proglottides at the larger (free) extremity of the specimens have the uterus filled with ova, and are therefore fairly ripe. One cestode exhibiting this condition of the posterior proglottides is $7\frac{1}{2}$ in. in length. This form appears to be related to *Tænia*.

(ii) A number of large cestodes occurred in the intestine of Blue Whale No. 3. They are devoid of acetabula. The scolex has the form of a soft pear-shaped head about 1 cm. long in a large specimen. At the base of this is a flattened discoid collar, having a diameter of 3 mm. The pyriform mass is embedded in the intestinal mucosa, while the collar appears to have the function of preventing it from penetrating too far. The proglottides are very short and wide, while the line of demarcation between them is not very clearly marked. One of these cestodes has a length of 27 in. Neither of the above has as yet been identified.

(*c*) *Acanthocephali.*—Members of this group were found parasitic in the intestines of all three species.

The following species have been identified:

B. physalus	*Echinorhynchus brevicollis.*
B. musculus	*E. porrigens.*
B. borealis	*E. turbinella.*

None of these are new records.[8]

(*d*) *Nematodes.*—In the Report for 1913 [9] an account was given of an apparently pathological structure found in the upper part of the renal circulation, and containing nematode ova. During the 1914 season further observations were made on this region, and on the kidney itself. A few specimens of the digitate structure were found; but, in addition, in the urinary vessels of twenty-one of the Finners, as well as in one Blue Whale and the Sejhval, nematode worms of some size were observed.

The following statements are the result of examination of specimens from *B. physalus*:

They have a very small diameter relative to their length, being perhaps $\frac{3}{16}$ in. thick, while the length of one incomplete specimen was 2 ft. 9 in. In the fresh state they are sometimes tinged with a reddish colour owing to the hue of the fluid with which the body cavity is filled.

The main ureter traverses the kidney for a great part of its length and is entered by numerous branches, which ramify in the mass of the kidney, where they terminate at the calyces of the lobules.

The worms are found partly in the urinary tube system, partly in the interlobular tissue. One extremity lies in the main vessels, while the other is to be found in the interlobular tissue. The point at which the worm passes into the urinary system is usually, if not always, situated in the wall of a calyx. The extralobular part of the parasite is embedded in a mass of connective tissue, in which it has a very tortuous course. It is probable that the presence of the nematode is responsible for the growth of the tissue in the regions where it occurs, since the connective tissue masses may be taken as indicative of the presence of the parasites which they invariably contain.

In one of these parasites ova were found which in appearance exactly resemble the free ova described last year. Those contained in the parent were, however, slightly larger than the ova in the digitate growth. The measurements are as follow:

	Ova in nematode section (6)	In digit section (9)
Average length	·0595 mm.	·0505 mm.
Maximum ,, ...	·0613 mm.	·0527 mm.
Minimum ,, ...	·0590 mm.	·0463 mm.
Average width	·0413 mm.	·0362 mm.
Maximum ,, ...	·0432 mm.	·0400 mm.
Minimum ,, ...	·0400 mm.	·0336 mm.

[8] Vide A. E. Shipley, *Archives de Parasitologie*, ii. No. 2, p. 262, 1899; *British Association Report* 1912, p. 180; *Ibid.* 1914, p. 141.

[9] *British Association Report* 1914, p. 141.

In that part of the *Terra Nova* Report [10] which deals with 'Parasitic Worms,' an account is given of *Crassicauda crassicauda*, Leiper and Atkinson, a nematode, probably a Filarian, which was recorded first by Creplin from a Northern Rorqual, and was also taken by Mr. D. G. Lillie from the renal tubules of Megaptera during the *Terra Nova* Expedition. Through the kindness of Mr. Bayliss of the British Museum (Natural History), I have been enabled to inspect specimens of this form, and, although I was not able to make detailed examination of them, it is my opinion that the nematodes taken from the kidney of various species of Balænoptera at Blacksod are very closely allied to *C. crassicauda*, if they are not identical with it.

IX. *Fœtuses.*

(1) *B. physalus.*—Unfortunately no success rewarded my efforts to obtain stages sufficiently young to be of value for embryological research. The smallest fœtus which I saw was that from Whale No. 15, and is 1 ft. 10½ in. long. This specimen has not the slightest trace of external hind limbs, the flukes being well developed, and it still retains a well-marked cervical flexure.

(2) *B. musculus* and *B. borealis.* No fœtus of either of these species was seen.

X. *Breeding Season.*

In my Report for 1913 [11] I suggested a method of calculating possible ages of the fœtuses from their size. Pursuing the same method with the six specimens observed in 1914, we have the following results:

Date of Measurement.	Size. Ft.	in.	Probable pairing time.
June 1	3	5¼	April (beginning).
,, 6	6	4	March (beginning).
,, 20	1	10½	May (end).
,, 26	8	2	February (end).
,, 30	4	3	April (end).
,, 30	6	8½	March (end).

In accordance with the above-mentioned method of calculating the ages of the fœtuses, and in consequence the probable pairing times of

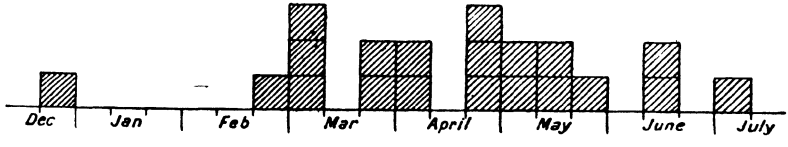


FIG. 4.—*B. physalus.* Diagram to show frequency of occurrence of pairing during the breeding season.

B. physalus, I have constructed a figure showing the distribution of the pairing times over those months in which it is suggested that they occur. The number of cases (20) is unfortunately small, but, notwithstanding this, it seems probable that the pairing occurs with greatest

[10] *Brit. Mus. Nat. Hist., British National Antarctic ('Terra Nova') Expedition* 1910, Natural History Report, 'Zoology,' vol. ii., No. 3, p. 29.
[11] *British Association Report* 1914, p. 143.

frequency during the three months March, April, and May; and I suggest that, when a sufficient quantity of data has been accumulated, the maximum may be found to occur in April (see fig. 4). All the fœtuses of 1911, 1913, and 1914 are included in the above figures.

TABLE I.—*B. physalus*. List of Specimens.

Number of Whale	Date when Measured	Sex	Total Length		Number of Whale	Date when Measured	Sex	Total Length	
			ft	in				ft	in
1	May 25	♂	61	0	17	June 25	♀	51	11
2	,, 25	♀	68	7	18	,, 26	♀	70	6
3	,, 26	♀	63	1	19	,, 27	♀	60	0
4	,, 26	♂	53	0	20	,, 27	♂	64	10
5	,, 27	♂	59	9	21	,, 29	♂	48	9
6	,, 28	♂	54	11	22	,, 30	♀	62	4
7	,, 28	♂	58	2	23	,, 30	♀	65	3
8	June 1	♀	68	3	24	July 1	♀	70	9
9	,, 6	♀	65	3	25	,, 15	♂	58	2
10	,, 6	♀	65	8	26	,, 16	♂	44	6
11	,, 16	♀	67	6	27	,, 16	♂	49	10
12	,, 17	♂	58	10	28	,, 16	♀	52	10
13	,, 17	♂	51	7	29	,, 20	♀	66	8
14	,, 19	♂	60	1	30	,, 30	♂	60	8
15	,, 20	♀	63	11	31	,, 30	♂	58	11
16	,, 24	♀	49	4					

TABLE II.—*B. musculus* L. List of Specimens.

Number of Whale	Date when Measured	Sex	Total Length		Number of Whale	Date when Measured	Sex	Total Length	
			ft	in				ft.	in.
1	June 27	♀	68	9	3	July 31	♀	73	1
2	July 20	♀	63	3	4	,, 31	♀	61	9

TABLE III.—*B. borealis* Lesson. One Specimen.

Date when Measured	Sex	Total Length	
		Ft	in
June 24	♀	39	0

TABLE IV.—Fœtuses *B. physalus*.

No. of Parent	Date when Measured	Sex	Total Length	
			ft	in
8	June 1	♂	3	5¾
10	,, 6	♂	6	4
15	,, 20	♀	1	10½
18	,, 26	♀	8	2
22	,, 30	♀(?)	4	3
23	,, 30	♂	6	8½

TABLE V.—*Balænoptera physalus*.—Measurements.

Number of Whale	No 1	No 2	No 3	No 4	No 5	No. 6
Sex	♂	♀	♀	♂	♂	♂
	ft. in.	ft. in.	ft in.	ft. in.	ft. in.	ft. in.
Total length	61 0	68 7	63 1	53 0	59 9	54 11
Tip of snout to spiracle	9 8	11 0	10 5	8 3	10 1	8 7
Tip of snout to posterior insertion of pectoral fin	19 8	21 8	20 6	17 3	19 8	17 7
Tip of snout to posterior insertion of dorsal fin	46 10	52 11	47 10	41 2	46 1	41 5
Tip of snout to centre of eye	11 10	13 8	13 0	10 5	12 6	10 6
Symphysis of jaw to centre of eye	14 8(?)	16 0	14 7	12 5	14 0	12 2
Centre of eye to anterior end of ear aperture	3 3	3 0	3 2	2 7	2 11	2 $8\frac{3}{4}$
Notch of flukes to posterior end of anus	16 8	18 2	18 2	14 4	16 6	15 8
Notch of flukes to anterior margin of umbilicus	29 2	32 3	30 2	25 7	28 9	27 0
	left	left	right	left	left	left
Length of pectoral fin, tip to anterior insertion	8 0	9 1	6 7	6 8	7 4	6 9
Length of pectoral fin, tip to posterior insertion	5 6	6 1	4 6	4 5	5 0	4 11
Median length of pectoral fin	6 6	7 5	5 7	5 $3\frac{1}{2}$	6 2	5 7
Pectoral fin, greatest breadth	1 $7\frac{1}{2}$	1 10	1 10	1 6	1 7	1 7
Dorsal fin, length	4 9	3 10	4 5	3 6	3 4	3 1
Dorsal fin, vertical height	1 8	1 8	1 6	1 5	1 8	1 1
Dorsal fin, falcation	—	0 8	—	0 $8\frac{1}{2}$	—	0 $3\frac{1}{2}$
Number of ventral furrows	61	79	58	67	61	51 (circ.)
		right		right		right
Pectoral fin, tip to anterior insertion	—	8 9	—	6 4	—	7 1
Pectoral fin, tip to posterior insertion	—	6 4	—	4 6	—	5 0
Median length, pectoral fin	—	7 0	—	5 3	-	5 11
Greatest width, pectoral fin	—	—	—	1 $5\frac{1}{2}$	—	1 $6\frac{1}{4}$

TABLE V.—*B. physalus.*—Measurements (*continued*).

Number of Whale	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
Sex	♂	♀	♀	♀	♀	♂
	ft. in.	ft. in.	ft. in.	ft. in.	ft in.	ft. in.
Total length	58 2	68 3	65 3	65 8	67 6	58 10
Tip of snout to spiracle	9 5	11 3	11 9	10 4	12 11	9 11
Tip of snout to posterior insertion of pectoral fin	18 2	21 10	23 0	21 4	22 7	18 10
Tip of snout to posterior insertion of dorsal fin	44 7	52 9	50 5	50 9	51 2	45 3
Tip of snout to centre of eye	11 0	13 8	14 2	13 4	14 4	12 1
			(mouth wide open)			
Symphysis of jaw to centre of eye	13 5	16 1	19 9	15 5	16 10	13 6
Centre of eye to anterior end of ear aperture	2 6½	3 0	2 9	3 2½	3 1	3 1
Notch of flukes to posterior end of anus	17 0	18 4	16 8	18 10	18 8	16 3
Notch of flukes to anterior margin of umbilicus	28 8	31 9	29 11	30 10	31 3	28 4
	left	left	left	left	right	right
Length of pectoral fin, tip to anterior insertion	7 0	7 10	8 8	9 6	8 1	7 7
Length of pectoral fin, tip to posterior insertion	4 10	5 9	6 4	5 7	5 7	5 0
Median length of pectoral fin	5 6½	6 8	7 1	7 1	6 10½	5 9
Pectoral fin, greatest breadth	1 6	1 10	1 11	1 10	1 11½	1 8½
Dorsal fin, length	3 7	5 0	4 6	4 6	4 2	3 8½
Dorsal fin, vertical height	1 3	1 7	1 3	1 10	1 4	1 1½
Dorsal fin, falcation	0 9	0 9	0 7	0 8½	0 4	0 5½
Number of ventral furrows	57	69	64 (circ.)	88	64	57 (circ.)
	right	right	right	right	left (tip damaged)	left (palmar surface)
Pectoral fin, tip to anterior insertion	7 3	7 8½	8 5	8 0	7 9	6 11
Pectoral fin, tip to posterior insertion	5 10	5 6½	6 0	5 8	5 7	5 0
Median length, pectoral fin	6 2	6 7	7 2	6 11	6 10	5 9
Greatest width, pectoral fin	1 7	1 10	1 10	1 10½	2 0	1 6½

TABLE V.—*B. physalus.*—Measurements (*continued*).

Number of Whale	No 13	No 14	No 15	No 16	No. 17	No. 18
Sex	♂	♂	♀	♀	♀	♀
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Total length	51 7	60 1	63 11	49 4	51 11	70 6
Tip of snout to spiracle	7 11	10 9	11 1	8 10	8 4	12 5
Tip of snout to posterior insertion of pectoral fin	15 11	20 5	19 8	15 2	18 11	22 7
Tip of snout to posterior insertion of dorsal fin	39 0	46 9	48 10	37 0	40 5	53 8
Tip of snout to centre of eye	10 2	13 0	13 4	9 7	10 2	14 6
Symphysis of jaw to centre of eye	13 0	14 10	15 7	11 2	11 11	16 11
Centre of eye to anterior end of ear aperture	2 5	3 0	3 2	—	2 $6\frac{1}{2}$	3 2
Notch of flukes to posterior end of anus	14 8	16 10	17 8	—	14 10	19 10
Notch of flukes to posterior margin of umbilicus	24 2	28 9	29 8	—	24 10	32 11
	left	left	right	right	left	left
Length of pectoral fin, tip to anterior insertion	6 9	8 6	8 2	6 $5\frac{1}{2}$	6 6	8 3
Length of pectoral fin, tip to posterior insertion	4 4	5 $9\frac{1}{2}$	5 6	4 $2\frac{1}{2}$	4 $9\frac{1}{2}$	5 8
Median length of pectoral fin	5 1	7 1	7 1	5 1	5 5	6 5
Pectoral fin, greatest breadth	1 6	1 $10\frac{1}{2}$	1 10	1 $3\frac{3}{4}$	1 $6\frac{1}{2}$	1 10
Dorsal fin, length	3 3	4 5	4 6	3 8	3 5	3 $8\frac{3}{4}$
Dorsal fin, vertical height	1 1	1 5	1 4	1 $3\frac{1}{2}$	1 2	1 6
Dorsal fin, falcation	0 $4\frac{1}{2}$	0 7	0 $5\frac{1}{2}$	0 $6\frac{1}{2}$	0 5	0 $5\frac{3}{4}$
Number of ventral furrows	60	—	73	65	—	66
			left (palmar surface)			
	right	right		left	right	right
Pectoral fin, tip to anterior insertion	6 9	8 0	8 0	6 0	6 0	7 8
Pectoral fin, tip to posterior insertion	4 7	5 $5\frac{1}{2}$	5 5	4 $0\frac{1}{2}$	4 5	5 9
Median length, pectoral fin	5 6	6 10	6 3	5 10	5 $5\frac{1}{2}$	6 11
Pectoral fin, greatest breadth	1 6	1 11	1 $9\frac{1}{2}$	1 $3\frac{1}{4}$	1 $6\frac{3}{4}$	1 $9\frac{1}{2}$

TABLE V.—*B. physalus.*—Measurements (*continued*).

Number of Whale	No 19	No 20	No 21	No 22	No. 23	No. 24
Sex	♀	♂	♂	♀	♀	♀
	ft in	ft in	ft. in.	ft. in.	ft in.	ft. in.
Total length	60 0	64 10	48 9	62 4	65 3	70 9
Tip of snout to spiracle	9 9	10 10	8 1	11 6½	11 4	12 0
Tip of snout to posterior insertion of pectoral fin	19 8	21 7	15 7	21 11	22 0	22 9
Tip of snout to posterior insertion of dorsal fin	45 9	50 0	38 0	48 3	50 8	53 10
Tip of snout to centre of eye	11 10	13 6	9 9	13 6	13 4	14 0
Symphysis of jaw to centre of eye	13 9	14 0	11 2	16 3	16 3	15 9
Centre of eye to anterior end of ear aperture	2 9½	3 2½	2 4¼	3 2	3 3	3 5½
Notch of flukes to posterior end of anus	17 0	18 1	14 0	16 4	17 0	19 11
Notch of flukes to posterior margin of umbilicus	28 1	30 5	23 7	28 2	29 2	34 6
	left	left	left	right	left	right
Length of pectoral fin, tip to anterior insertion	7 11	8 5	6 4	7 7½	7 10	8 9
Length of pectoral fin, tip to posterior insertion	5 1	5 11	4 6	4 9	4 0	5 2
Median length of pectoral fin	7 1	7 0	5 6	6 0½	5 10	6 2
Pectoral fin, greatest breadth	1 8½	1 10	1 5½	1 7	1 11	1 0(?)
Dorsal fin, length	4 4	4 3	3 10½	4 0	3 3	4 6
Dorsal fin, vertical height	1 4	1 6¾	1 4	1 4	1 6	1 5
Dorsal fin, falcation	0 9	0 11	0 5½	0 8	0 8	0 5½
Number of ventral furrows	56 (circ.)	71	68	62	76	65
	right broken off. Length of stump	right	right	left	right	left
Pectoral fin, tip to anterior insertion	—	8 4½	6 7½	7 9	6 11	9 6
Pectoral fin, tip to posterior insertion	3 8	5 9	4 2	4 10	4 3	5 1
Median length, pectoral fin	—	7 1	5 5	6 0	5 9	7 7
Pectoral fin, greatest breadth	—	1 10½	1 4½	—	1 9¾	1 6

TABLE V.—*B. physalus.*—Measurements (*continued*).

Number of Whale	No. 25	No. 26	No. 27	No. 28	No. 29	No. 30	No. 31
Sex	♂	♂	♂	♀	♀	♂	♂
	ft. in.	ft in	ft in.	ft in	ft. in	ft in.	ft. in.
Total length	58 2	44 6	49 10	58 10	66 8	60 8	58 11
Tip of snout to spiracle	9 6	6 0	8 1	8 3	10 11	—	10 10
Tip of snout to posterior insertion of pectoral fin	19 2	13 10	16 1	17 1	21 5	21 11	20 7
Tip of snout to posterior insertion of dorsal fin	45 4	34 3	38 2	40 4	49 10	49 2	46 2
Tip of snout to centre of eye	11 8	7 10	9 5	10 0	13 10	14 7	13 0
Symphysis of jaw to centre of eye	13 11	9 10	12 2	12 5	15 9	16 7	14 10
Centre of eye to anterior end of ear aperture	2 8	1 3	2 5	2 4½	3 0½	2 10½	2 11
Notch of flukes to posterior end of anus	16 4	12 5	13 11	14 5	18 1	16 2	15 6
Notch of flukes to posterior margin of umbilicus	28 0	21 0	23 8	24 11	30 8	30 8	26 3
	left	left	left	left	left		left
Length of pectoral fin, tip to anterior insertion	7 3	5 5	6 0	6 7	7 11	—	8 4
Length of pectoral fin, tip to posterior insertion	5 1	3 9	4 2	4 3	5 1	—	5 5
Median length of pectoral fin	5 10	4 5	5 0	5 3	6 4	—	6 7
Pectoral fin, greatest breadth	1 7	1 3½	1 3¾	1 4	1 8¼	—	1 8½
Dorsal fin, length	4 1	2 5(?)	3 2	1 8	4 10	4 10	4 1
Dorsal fin, vertical height	1 2	—	1 2	1 2½	1 7	1 6	1 9
Dorsal fin, falcation	0 3½	—	0 5½	0 4	0 9½	0 7½	0 9½
Number of ventral furrows	—	77	65	65	64	71	60
			right	right			right
Pectoral fin, tip to anterior insertion	—	—	6 4	6 7	—	—	7 11
Pectoral fin, tip to posterior insertion	—	—	4 4	4 3	—	—	5 8
Median length, pectoral fin	—	—	5 0	5 4	—	—	6 9
Pectoral fin, greatest breadth	—	—	1 4½	1 4¾	—	—	1 8½

Measurements — TABLE VI. *B. musculus.* TABLE VII. *B. borealis.*

Number of Whale	No. 1	No. 2	No. 3	No. 4	No. 1
Sex	♀	♀	♀	♀	♀
	ft. in.	ft. in.	ft. in.	ft in.	ft. in.
Total length	68 9	63 3	73 1	61 9	39 0
Tip of snout to spiracle	10 9	9 7	12 3	8 10	6 0
Tip of snout to posterior insertion of pectoral fin	21 8	20 8	25 1	19 9	13 2
Tip of snout to posterior insertion of dorsal fin	51 4	47 4	57 6	47 3	27 10
Tip of snout to centre of eye	13 4	10 3	14 7	12 0	7 11
Symphysis of jaw to centre of eye	16 5	15 6	19 8	14 4	8 3
Centre of eye to anterior end of ear aperture	3 6	3 0½	3 9	2 11	2 2½
Notch of flukes to posterior end of anus	20 5	18 2	19 6	18 2	10 9
Notch of flukes to anterior margin of umbilicus	32 10	20 3	33 2	29 7	13 2
Length of pectoral fin, tip to anterior insertion	10 8	—	10 4	—	5 4
Length of pectoral fin, tip to posterior insertion	7 0	—	6 8¾	—	3 8
Median length of pectoral fin	8 0	—	8 7	—	4 2
Pectoral fin, greatest breadth	2 3½	—	2 7	—	1 1
Dorsal fin, length	1 11	1 11	2 9¼	—	2 2
Dorsal fin, vertical height	1 0	0 4½	0 9¾	—	1 5
Dorsal fin, falcation	0 2¾	—	0 1¼	—	0 6
Number of ventral furrows	72	66	65	74	—
Pectoral fin, tip to anterior insertion	11 0	—	—	—	5 6
Pectoral fin, tip to posterior insertion	7 7	—	—	—	3 7
Median length, pectoral fin	8 11	—	—	—	4 3
Greatest width, pectoral fin	2 2½	—	—	—	1 1

TABLE VIII.—*B. physalus.*—Fœtuses.—Measurements.

	No. 8	No 10	No. 15	No. 18	No 22	No 23
Number of parent						
Sex of fœtus	♂	♂	♀	♀	♀ (?)	♂
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft in
Total length	3 $5\frac{3}{4}$	6 4	1 $10\frac{1}{2}$	8 2	4 3	6 $8\frac{1}{2}$
Tip of snout to spiracle	0 $5\frac{3}{4}$	1 0	0 $2\frac{1}{16}^{3}$	1 $1\frac{1}{2}$	0 6	0 $9\frac{1}{2}$
Tip of snout to posterior insertion of pectoral fin	1 $2\frac{1}{4}$	2 $2\frac{3}{4}$	0 $7\frac{2}{4}$	2 $6\frac{1}{2}$	1 $5\frac{1}{2}$	2 $1\frac{1}{2}$
Tip of snout to posterior insertion of dorsal fin	2 $7\frac{1}{4}$	4 9	1 $4\frac{1}{2}$	6 1	3 $2\frac{1}{2}$	4 $9\frac{1}{2}$
Tip of snout to centre of eye	0 $8\frac{1}{4}$	1 3	0 $3\frac{1}{16}^{1}$	1 5	0 $8\frac{1}{2}$	1 $1\frac{1}{2}$
Symphysis of jaw to centre of eye	0 $9\frac{1}{2}$	1 4	0 $4\frac{1}{4}$	1 5	—	1 $2\frac{1}{2}$
Centre of eye to anterior end of ear aperture	0 $2\frac{?}{4}$	0 5	0 $1\frac{3}{4}$	0 $5\frac{1}{2}$	—	0 $4\frac{1}{2}$
Notch of flukes to posterior margin of anus	1 0	1 $11\frac{1}{2}$	0 7	2 4	1 2	1 $9\frac{1}{2}$
Notch of flukes to anterior margin of umbilicus	1 $8\frac{1}{4}$	3 $1\frac{1}{2}$	0 11	3 8	1 10	3 0
	right	left	right	left	left	left
Length of pectoral fin, tip to anterior insertion	0 $5\frac{1}{4}$	0 10	0 $3\frac{1}{8}$	1 $3\frac{1}{4}$	0 6	0 $9\frac{1}{2}$
Length of pectoral fin, tip to posterior insertion	0 3^{3}	0 $6\frac{3}{4}$	0 $2\frac{1}{4}$	0 $9\frac{1}{2}$	0 $4\frac{1}{4}$	0 $7\frac{1}{2}$
Median length of pectoral fin	0 $4\frac{1}{4}$	0 $8\frac{1}{2}$	0 $2\frac{3}{4}$	1 1	0 5	0 $8\frac{1}{2}$
Pectoral fin, greatest breadth	0 $1\frac{1}{4}$	0 $2\frac{1}{4}$	0 $\frac{3}{4}$	—	0 $1\frac{1}{2}$	0 $2\frac{1}{4}$
Dorsal fin, length	0 $2\frac{1}{4}$	0 $4\frac{1}{2}$	0 $1\frac{3}{16}^{3}$	0 6	—	0 $4\frac{1}{2}$
Dorsal fin, vertical height	0 1	0 $2\frac{1}{4}$	0 $\frac{3}{8}$	0 $2\frac{3}{4}$	—	0 $1\frac{1}{2}$
Dorsal fin, falcation	0 $0\frac{7}{8}$	0 1	0 $\frac{1}{16}$	0 $1\frac{1}{4}$	—	0 1
Width of flukes, tip to tip	0 8	1 5	0 $4\frac{1}{4}$	1 $10\frac{1}{2}$	0 $10\frac{1}{2}$	—
Number of ventral furrows	(could not be counted)	63	(none)	56	(could not be counted)	50
		right		right	right	right
Measurements of pectoral fin—						
Tip to anterior insertion	—	0 $9\frac{1}{2}$	—	1 1	0 6	0 $9\frac{1}{2}$
Tip to posterior insertion	—	0 $6\frac{1}{2}$	—	0 10	0 $4\frac{1}{2}$	0 7
Median length	—	0 8	—	0 11	0 $5\frac{1}{2}$	0 $8\frac{1}{2}$
Greatest breadth	—	0 $2\frac{3}{8}$	—	0 $3\frac{1}{4}$	0 $1\frac{3}{8}$	0 $2\frac{1}{2}$

TABLE IX —*B. physalus.*—Proportions.*

Number of Whale	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Sex	♂	♀	♀	♂	♂	♂	♂	♀	♀	♀
Total length	ft. in. 61 0	ft. in. 68 7	ft. in 63 1	ft in. 53 0	ft in. 59 9	ft. in. 54 11	ft. in. 58 2	ft. in. 68 3	ft. in. 65 3	ft. in. 65 8
	%	%	%	%	%	%	%	%	%	%
Tip of snout to spiracle	15·85	13·37	16 14	15·56	16·88	15·63	16·19	16·48	17·75	15·73
Tip of snout to posterior insertion of pectoral fin	32·24	31·59	32 49	32·55	32·92	32·02	31·23	31·99	35·25	32·48
Tip of snout to posterior insertion of dorsal fin	76·78	77·34	75·82	77·66	77·13	75·43	76·65	77·29	77·27	77·29
Tip of snout to centre of eye	19·40	19 93	20 61	19 65	20·92	19 12	18·91	20·02	21·71 (Mouth wide open)	20·31
Symphysis of jaw to centre of eye	24·04	23·33	23·12	23·43	23·42	22·16	23·06	23 57	30·26	23·48
Centre of eye to anterior end of ear aperture	5·33	4·37	5·02	4 87	4·88	4·97	4·37	4·40	4·21	4·89
Notch of flukes to posterior end of anus.	27·32	26 50	28·80	27·04	27·62	28·53	29·22	26 86	25·54	28·68
Notch of flukes to anterior margin of umbilicus	47·82	47 02	47·82	48·26	48·11	49 16	49·28	46·51	44·78	46·96
	left	left	right	left	left	left	left	left	left	left
Length of pectoral fin, tip to anterior insertion	13 11	13·24	10·43	12·58	12·27	12·29	12·03	11·48	13·28	14·46
Length of pectoral fin, tip to posterior insertion	9 02	8 87	7·134	8·43	8·37	8 95	8·31	8·42	9 71	8·50
Median length of pectoral fin	10·65	10 81	8 85	9 99	10·32	10·16	9 53	9·77	10·85	10·78
Pectoral fin, greatest breadth	2·66	2·67	2 90	2 83	2·65	2·88	2·58	2·69	2·94	2·79
Dorsal fin, length	7·79	5·59	7·00	6·60	5·58	5·61	6·16	7·33	9·90	6·85
Dorsal fin, vertical height	2·73	2 43	2·38	2·67	2·79	1·97	2·15	2·32	1·92	2·79
		right		right		right	right	right	right	right
Dorsal fin, falcation	—	·97	—	1·38	—	·53	1·29	1·10	·894	1·07
Pectoral fin, tip to anterior insertion	—	12·74	—	11·95	—	12·60	12·47	11·29	12·90	12·18
Pectoral fin, tip to posterior insertion	—	9·23	—	8 48	—	9·10	10·02	8·85	9·19	8·63
Median length, pectoral fin	—	10·21	—	9·90	—	10·77	10·60	9·65	10·98	10·53
Greatest breadth, pectoral fin	—	—	—	2 75	—	2·81	2·72	2·69	2·81	2·86

* Proportions = measurements reduced to percentages of total length.

TABLE IX.—*B. physalus.*—Proportions (*continued*).

Number of Whale	No 11	No. 12	No 13	No 14	No. 15	No. 16	No 17	No. 18	No. 19	No. 20
Sex	♀	♂	♂	♂	♀	♀	♀	♀	♀	♂
Total length	ft. in. 67 6	ft. in. 58 10	ft. in. 51 7	ft. in 60 1	ft. in 63 11	ft. in. 49 4	ft. in. 51 11	ft. in. 70 6	ft. in. 60 0	ft. in. 64 10
Tip of snout to spiracle	% 19·14	% 16 86	% 15 35	% 17 89	% 17·34	% 17 91	% 16·05	% 17·61	% 16·25	% 16·70
Tip of snout to posterior insertion of pectoral fin	33·46	32·01	34 09	33 98	30·77	30·75	36·43	32·03	32 78	33·29
Tip of snout to posterior insertion of dorsal fin	75·80	76·91	75·60	77·82	76·40	75·01	77·84	76·12	76·26	77·13
Tip of snout to centre of eye	21·23	20·54	19 71	21·64	20·85	19·43	19·58	20 56	19·72	20·82
Symphysis of jaw to centre of eye	24·94	22 95	25·2	24·69	24·38	22 63	22·95	24 00	22·92	21·59
Centre of eye to anterior end of ear aperture	4·82	5 53	4·69	4 99	4·96	—	4·90	4·49	4·65	4·95
Notch of flukes to posterior end of anus.	27 65	27·62	28 43	28·02	27·64	—	28·57	28·13	28·33	27·89
Notch of flukes to anterior end of umbilicus	46 29	48·16	46·85	47·82	45·88	—	47·83	46·69	46·80	46·91
Length of pectoral fin, tip to anterior insertion	right 11 98	right 12·89	left 13·08	left 14·15	right 12·77	right 13·05	left 12·53	left 11·70	left 12 92	left 12·98
Length of pectoral fin, tip to posterior insertion	8·27	8·50	8·40	9 64	8·60	8·53	9·23	8·04	8 47	9·13
Median length of pectoral fin	10·19	9 77	9·85	11·79	11·09	10·30	10 43	9·10	11·8	10·80
Pectoral fin, greatest breadth	2 90	2 90	2 91	3·12	2·87	2·66	2 97	2·60	2 85	2·83
Dorsal fin, length	6·17	6 30	6 30	7·35	7·04	7·43	6·58	5 29	7·22	6·56
Dorsal fin, vertical height	1·98	1·91	2 10	2·36	2·09	2·62	2 25	2 13	2·22	2·41
Dorsal fin, falcation	left ·49	left ·78	·71	·97	·72	1·09	·80	0·68	1·25	1·41
Pectoral fin, tip to anterior insertion	11·48	11·76	right 13 08	right 13 31	left 12·51	left 12·16	right 11·55	right 10·87	right broken off	right 12·91
Pectoral fin, tip to posterior insertion	8·27	8·5	8·89	9 08	8·60	8·19	8·71	8·16	—	8·87
Median length, pectoral fin	10·13	9·77	10·66	11·37	9·78	11·82	10·52	9·81	—	10·90
Greatest breadth, pectoral fin	2·96	2·59	2·91	3·19	2·81	2·58	3·01	2·54	—	2·89

TABLE IX.—*B. physalus*.—Proportions (*continued*).

Number of Whale	No. 21	No. 22	No. 23	No. 24	No. 25	No. 26	No. 27	No. 28	No. 29	No. 30	No. 31
Sex	♂	♀	♀	♀	♂	♂	♂	♀	♀	♂	♂
Total length	ft. in. 48 9	ft. in. 62 4	ft. in. 65 3	ft. in. 70 9	ft. in. 58 2	ft. in. 44 6	ft. in. 49 10	ft. in. 52 10	ft. in. 66 8	ft. in. 60 8	ft. in. 58 11
Tip of snout to spiracle	% 16·58	% 18·45	% 17·37	% 16·96	% 16·40	% 13·48	% 16·22	% 15·62	% 16·38	% —	% 18·39
Tip of snout to posterior insertion of pectoral fin	31·96	35·17	33·76	32·16	32·95	31·09	32·28	32·33	32·12	36·13	34·93
Tip of snout to posterior insertion of dorsal fin	77·94	77·41	77·64	76·08	77·93	76·96	76·60	76·33	74·74	81·06	78·36
Tip of snout to centre of eye	20·00	21·66	20·43	19·79	20·05	17·60	18·90	18·92	20·75	24·04	22·07
Symphysis of jaw to centre of eye	22·91	26·07	24·90	22·26	23·92	22·10	24·42	23·51	23·62	27·34	25·18
Centre of eye to anterior end of ear aperture	4·83	5·08	4·98	4·89	4·58	2 81	4·85	4·49	4·67	4·74	5·06
Notch of flukes to posterior end of anus	28·72	26·20	32·05	28·15	28·08	27·9	27·93	27·29	27·13	26·65	26·31
Notch of flukes to anterior end of umbilicus	48 38	45·19	44·70	48·76	48·12	47·20	47·49	47·17	45·99	50·55	44·55
Length of pectoral fin, tip to anterior insertion	left 12 99	right 12 44	left 12 00	right 12 37	left 12·47	left 12·17	left 12·04	left 12·46	left 11·88	—	left 14·15
Length of pectoral fin, tip to posterior insertion	9·23	7·75	6·13	7·30	8·74	8·52	8·36	8·04	7·69	—	9·17
Median length of pectoral fin	11·28	9·63	8 94	8·72	10·02	9 93	10·03	9·94	9·50	—	11·18
Pectoral fin, greatest breadth	2·99	—	2·94	—	2·72	2 90	2·63	2·52	2·50	—	2·9
Dorsal fin, length	7·95	6 42	4·98	5·18	7·02	5·43	6·44	3·15	7·25	7·97	6·93
Dorsal fin, vertical height	2·73	2·14	2·30	2·00	2·00	—	2·34	2·29	2·37	2·47	2·97
Dorsal fin, falcation	·94	1·07	1·02	·64	0·50	—	0·92	0·63	1·19	1·03	1·34
Pectoral fin, tip to anterior insertion	right 13·59	left 12·23	right 10·60	left 12·1	—	—	right 12·67	right 12·46	—	—	right 13·44
Pectoral fin, tip to posterior insertion	8·55	7·62	6·51	7·18	—	—	8·70	8·04	—	—	9·62
Median length, pectoral fin	11·11	9·63	8·81	10·72	—	—	10·03	10·09	—	—	11·72
Greatest breadth, pectoral fin	2·82	2·54	2·78	2·12	—	—	2·76	2·68	—	—	2·9

Proportions.—

TABLE X. *B. musculus.*

Number of Whale	No. 1	No. 2	No. 3	No. 4
Sex	♀	♀	♀	♀
	ft. in.	ft. in.	ft. in.	ft. in.
Total length	68 9	63 3	73 1	61 9
	%	%	%	%
Tip of snout to spiracle	15·63	15·16	16·76	14·31
Tip of snout to posterior insertion of pectoral fin	31·52	32·68	34·33	31·99
Tip of snout to posterior insertion of dorsal fin	74·66	74·84	78·66	76·52
Tip of snout to centre of eye	19·39	16·21	19·95	19·44
Symphysis of jaw to centre of eye	23·88	24·51	26·97	23·21
Centre of eye to anterior end of ear aperture	5·09	4·78	5·13	4·72
Notch of flukes to posterior end of anus	29·70	28·73	26·68	29·43
Notch of flukes to anterior end of umbilicus	47·75	32·02	45·38	47·90
	left			
Length of pectoral fin, tip to anterior insertion	15·52	—	14·14	—
Length of pectoral fin, tip to posterior insertion	10·18	—	9·24	—
Median length of pectoral fin	11·63	—	11·74	—
Pectoral fin, greatest length	3·33	—	3·53	—
Dorsal fin, length	2·79	3·03	3·79	—
Dorsal fin, vertical height	1·45	·59	1·08	—
Dorsal fin, falcation	·33	—	·14	—
	right			
Pectoral fin, tip to anterior insertion	16·0	—	—	—
Pectoral fin, tip to posterior insertion	11·03	—	—	—
Median length, pectoral fin	12·97	—	—	—
Greatest breadth, pectoral fin	3·21	—	—	—

TABLE XI. *B. borealis.*

Number of Whale	No. 1
Sex	♀
	ft. in.
Total length	39 0
	%
Tip of snout to spiracle	15·38
Tip of snout to posterior insertion of pectoral fin	33·77
Tip of snout to posterior insertion of dorsal fin	71·25
Tip of snout to centre of eye	20·30
Symphysis of jaw to centre of eye	21·15
Centre of eye to anterior end of ear aperture	5·66
Notch of flukes to posterior end of anus	27·57
Notch of flukes to anterior end of umbilicus	33·77
	left
Length of pectoral fin, tip to anterior insertion	13·68
Length of pectoral fin, tip to posterior insertion	9·40
Median length of pectoral fin	10·69
Pectoral fin, greatest length	2·78
Dorsal fin, length	5·56
Dorsal fin, vertical height	3·63
Dorsal fin, falcation	1·28
	right
Pectoral fin, tip to anterior insertion	14·10
Pectoral fin, tip to posterior insertion	9·19
Median length, pectoral fin	10·90
Greatest breadth, pectoral fin	2·78

TABLE XII.—*B. physalus*.—Fœtuses.—Proportions.

Number of parent	No. 8	No. 10	No. 15	No. 18	No. 22	No. 23
Sex of fœtus	♂	♂	♀	♀	♀ (?)	♂
Total length	ft. in. 3 5¾	ft. in. 6 4	ft. in. 1 10½	ft. in. 8 2	ft. in. 4 8	ft. in. 6 8½
	%	%	%	%	%	%
Tip of snout to spiracle	13·77	15·79	13·08	13·77	11·77	11·8
Tip of snout to posterior insertion of pectoral fin	34·14	35·20	36·04	31·13	34·31	31·67
Tip of snout to posterior insertion of dorsal fin	74·87	75·01	76·76	74·49	75·50	71·44
Tip of snout to centre of eye	19·76	19·73	18·61	17·35	16·29	16·77
Symphysis of jaw to centre of eye	22·97	21·05	19·77	17·35	—	18·01
Centre of eye to anterior end of ear aperture	6·65	6·58	8·14	5·87	—	5·90
Notch of flukes to posterior margin of anus	29 02	30·92	32·56	28·58	27·45	26·71
Notch of flukes to anterior margin of umbilicus	48·98	49·34	51·17	44·90	43·13	44·72
	right	left	right	left	left	left
Length of pectoral fin, tip to anterior insertion	12·70	13·16	14·54	15·56	11·77	11·80
Length of pectoral fin, tip to posterior insertion	8·98	8·88	8·31	9·69	8·33	9·32
Median length of pectoral fin	10·18	11·19	12·79	13·26	9·58	10·55
Pectoral fin, greatest breadth	2·99	2·96	3·49	—	2·94	2·80
Dorsal fin, length	5·44	6·25	3·96	6·12	—	5·59
Dorsal fin, vertical height	2·40	2·96	1·83	2·81	—	2·17
Dorsal fin, falcation	2·12	1·32	·305	1·28	—	1·24
Width of flukes, tip to tip	19·16	22·37	19·77	22·96	20·59	—
Measurements of pectoral fin—		right		right	right	right
Tip to anterior insertion	—	12·50	—	13·26	11·77	11·80
Tip to posterior insertion	—	8·55	—	10·21	8·82	8·70
Median length	—	10·53	—	11·23	10·78	10·55
Greatest breadth	—	3·13	—	3·32	2·70	3·11

Nomenclator Animalium Genera et Sub-Genera.—Report of the Committee, consisting of Dr. CHALMERS MITCHELL (*Chairman*), Rev. T. R. R. STEBBING (*Secretary*), Dr. M. LAURIE, Professor MARETT TIMS, *and* Dr. A. SMITH WOODWARD.

THE war with Germany precluded the Committee from remitting any money to Berlin, and we have no recent knowledge as to the progress of the compilation. Accordingly we have not applied to the Treasurer for payment of the grant, which, by the rules of the Association, now lapses.

The Committee asks for reappointment without a grant. The 'Nomenclator' was so far advanced, and promised to be so useful to systematic zoologists, that the Committee desires to be in a position, when peace comes, to inquire into and report on what has happened to the work, and to consider if any useful steps could be taken in this country.

Marsupials.—Report of the Committee, consisting of Professor A. DENDY (*Chairman*), Professors T. FLYNN *and* G. E. NICHOLLS (*Secretaries*), *and* Professors E. B. POULTON *and* H. W. MARETT TIMS, *appointed to obtain, as nearly as possible, a representative Collection of Marsupials for work upon (a) the Reproductive Apparatus and Development, (b) the Brain.*

THE sum of 100*l.* granted to this Committee was placed in the hands of Professor Masson, of Melbourne. 50*l.* of this was paid over to Professor Flynn in September last, and Professor Masson kindly undertook to make arrangements for further payments as required. The Chairman has received information to the following effect from Professor Flynn:—

It has not been possible to do more than just commence the work of the Committee, and on that account we ask that the unexpended balance of the grant may be retained.

It is necessary to point out that if the grant is to be economically used, it should be spent principally during the breeding season of Marsupials, since only at that time can material be got which fulfils both objects of the grant. The main breeding season of Marsupials in Tasmania is during late June and July, and for Monotremes in September and October. In other words, as regards Marsupials, the first breeding season since the receipt of the grant is only now commencing, and, in the case of the Monotremes (for any organised attempt on which the grant arrived too late last year), the breeding season does not occur for another three months.

It has, however, been necessary to obtain reproductive organs in the resting stage, and, in accordance with this, collections of the following genera have been made:—*Dasyurus*, *Sarcophilus*, *Bettongia*,

Potorous, *Dromicia*, *Perameles*, *Halmaturus*, *Pseudochirus*, *Vulpecula*, *Phascolomys*, *Ornithorhynchus*, and *Echidna*.

The total expenditure to date is 21*l*. 17*s*. 6*d*. An endeavour has been made to keep skins and skulls of as many animals as possible, and it is confidently expected that the value of these will be equal to a considerable amount of the grant.

The Committee desires to retain the balance of the grant, and applies for reappointment.

Biology of the Abrolhos Islands.—Interim Report of the Committee, consisting of Professor W. A. Herdman (*Chairman*), Professor W. J. Dakin (*Secretary*), Dr. J. H. Ashworth, *and* Professor F. O. Bower, *appointed for the investigation of the Biology of the Abrolhos Islands and the North-West Coast of Australia (North of Shark's Bay to Broome), with particular reference to the Marine Fauna.*

Owing to the war and several other unforeseen circumstances, the departure of the expedition for the Abrolhos Islands has had to be delayed. Owing to delays in the mail it was near the end of May before intimation was received from the Government Grant Committee of the Royal Society that a grant for the purposes of the Abrolhos investigation had been passed. Without this the full programme could not have been carried out. Everything has now been arranged, and, unless some extraordinary developments take place through the war, the expedition will leave Perth on November 1. Equipment has been ordered to the amount of 34*l*. out of the British Association grant of 40*l*, but no accounts are to hand, and nothing has yet been paid out.

The Committee asks for reappointment for the coming year without further grant.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Mr. E. S. Goodrich (*Chairman*), Dr. J. H. Ashworth (*Secretary*), Mr. G. P. Bidder, Professor F. O. Bower, Dr. W. B. Hardy, Dr. S. F. Harmer, Professor S. J. Hickson, Sir E. Ray Lankester, Professor W. C. McIntosh, *and* Dr. A. D. Waller.

The British Association table at Naples has not been occupied during the current financial year. In April 1914, Mr. J. Mangan, of the Government School of Medicine, Cairo (now Professor of Zoology in Galway), applied for the use of the table from Sept. 12 onwards for four or five weeks, and he was appointed to the table for that period. On Sept. 4, however, he wrote from Cairo as follows: 'As all leave has been stopped in the Government service here, I have had to cancel my plans for working during September and October at the British Association table at Naples. . . . Will you please convey to

the Committee my thanks for the facilities so kindly offered to me, and my regret that I cannot avail myself of them?'

Mrs. Pixell-Goodrich has published ('Quart. Journ. Micr. Sci.,' vol. 61, pp. 81-104, pl. viii., 1915) an account of the researches on 'The Life-history of the Sporozoa of Spatangoids' which she carried out in part while occupying the British Association table at Naples in the spring of 1914.

Marine Laboratory, Plymouth.—Report of the Committee, consisting of Professor A. DENDY (*Chairman and Secretary*), Sir E. RAY LANKESTER, Mr. E. S. GOODRICH, *and* Professor J. P. HILL, *appointed to nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.*

MR. J. S. DUNKERLY, to whom the use of the table was granted for one month in 1914, reports as follows:

'At Plymouth last summer I was collecting material from fishes' gall-bladders for the study of Myxosporidian life-histories. I obtained some very good material, especially of *Ceratomyxa drepanopsettæ*, which supports, so far as I have examined it, the theory of Myxosporidian Cytology put forward in a paper at present printing in "Edinburgh Proc. R.S.," entitled "*Agarella gracilis*, a new species of Myxosporidian from *Lepidosiren paradoxa*." Unfortunately the war has intervened and I am unable at present to continue my research work, but I hope to continue my investigation of the material, and to publish the results thereof after the war.'

Since the last meeting only one application for the use of the table has been received. This application was granted, but the applicant subsequently withdrew owing to his employment on munition work.

The Natural History of the Isle of Man.—Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Mr. P. M. C. KERMODE (*Secretary*), Dr. W. T. CALMAN, Rev. J. DAVIDSON, Mr. G. W. LAMPLUGH, Professor E. W. MACBRIDE, *and* Lord RAGLAN, *appointed to make a Survey thereof.*

THE Committee regret to report that under the conditions caused by the war they find it impossible now to carry on their proposed investigation of the Natural History of the Isle of Man, and, as they see no prospect of so doing for some considerable time, they think it better that they should not be reappointed at the forthcoming meeting of the British Association.

Atlas, Textual, and Wall Maps for School and University use.—*Report of the Committee, consisting of* Professor J. L. MYRES (*Chairman*), Rev. W. J. BARTON (*Secretary*), Professor R. L. ARCHER, Dr. R. N. RUDMOSE BROWN, Mr. G. G. CHISHOLM, Colonel C. F. CLOSE,* Mr. G. F. DANIELL, Professor H. N. DICKSON, Mr. A. R. HINKS, Mr. O. J. R. HOWARTH, Colonel Sir D. A. JOHNSTON, *and* Mr. E. A. REEVES, *appointed to inquire into the Choice and Style thereof.*

[PLATES VII. AND VIII.]

PART I.

THE Committee was appointed at the Dundee Meeting of the Association, and presented an interim Report at the Birmingham Meeting, dealing mainly with the contents and arrangement of a School Atlas for senior and for junior students, and suggesting a number of points on which an expression of teachers' opinions was desired. Copies of this interim Report have been distributed widely among school teachers, as well as to members of the Geographical Association, and some interesting criticisms and suggestions have been received, for which the Committee desires to express its thanks. The Secretary and other members of the Committee have taken various opportunities of meeting geographers and teachers informally at meetings in London and in the provinces, and of learning their views at first hand. Many suggestions gathered in this way are embodied in the Committee's Report.

The paragraphs which follow, dealing with the choice and arrangement of maps in an Atlas, or in a systematic series of wall maps, are reproduced with modification from the interim Report. Those, on the other hand, which deal with problems of style and draughtsmanship are new, and represent the principal task of the Committee in the last two years. The grant made by the Association for experimental cartography has been of the greatest value, and the thanks of the Committee are due to the Royal Geographical Society for facilities for the preparation of specimen sheets, the most important of which are reproduced here.

Contents and Arrangement of a School Atlas.

While not desiring in any way to stereotype the contents of a School Atlas, the Committee submits its syllabus of maps as a concrete example of what may fairly be included in such a publication.

The needs of junior and senior students differ widely, and it was found necessary from the outset to deal with them separately. But throughout the inquiry it has been the object of the Committee to provide as far as possible for a Senior and a Junior Atlas which should be consistent in their general plan and execution.

* Retired from Committee at the outbreak of war.

Senior School Atlas.

'Royal' paper (25 × 20 in.) will give a map 10½ × 8½ in. on the single page. Double-page maps would, of course, be best mounted on guards; but this arrangement is too costly for a School Atlas, and the practical difficulty is best overcome by printing such maps as two single pages *with an overlap*, and binding them as usual. It is essential that all the maps should be readily comparable. In particular, all world maps should be on the same projection. As few scales should be employed as possible. All the Continents should be shown on the same scale; unless, as below, a double scale is used for Europe. For larger-scale maps simple multiples of this scale are recommended, as will be seen from a comparison of the lists which follow. For questions of scale, projection, lettering, and other points of style and draughtsmanship reference should be made to the second half of this Report.

In maps of climate the annual distributions are less useful for teaching than the seasonal, and it would be a great gain if the summer and winter conditions were represented on maps of the North and South Hemispheres. It will be noted in the appended list that the double-page maps of the Continents each allows for two insets; for India three seasons should be represented. Maps representing the distribution of population have high value; geological and vegetation maps should be included if possible, but are not essential. Historical and economic maps belong to special atlases or to text-books, and should be excluded from the School Atlas. It will be enough to indicate the busier regions, industrial and agricultural, if these do not emerge sufficiently clearly from the population map.

It has been suggested that world distribution maps would be better placed at the end than at the beginning of an Atlas.

List of Maps.

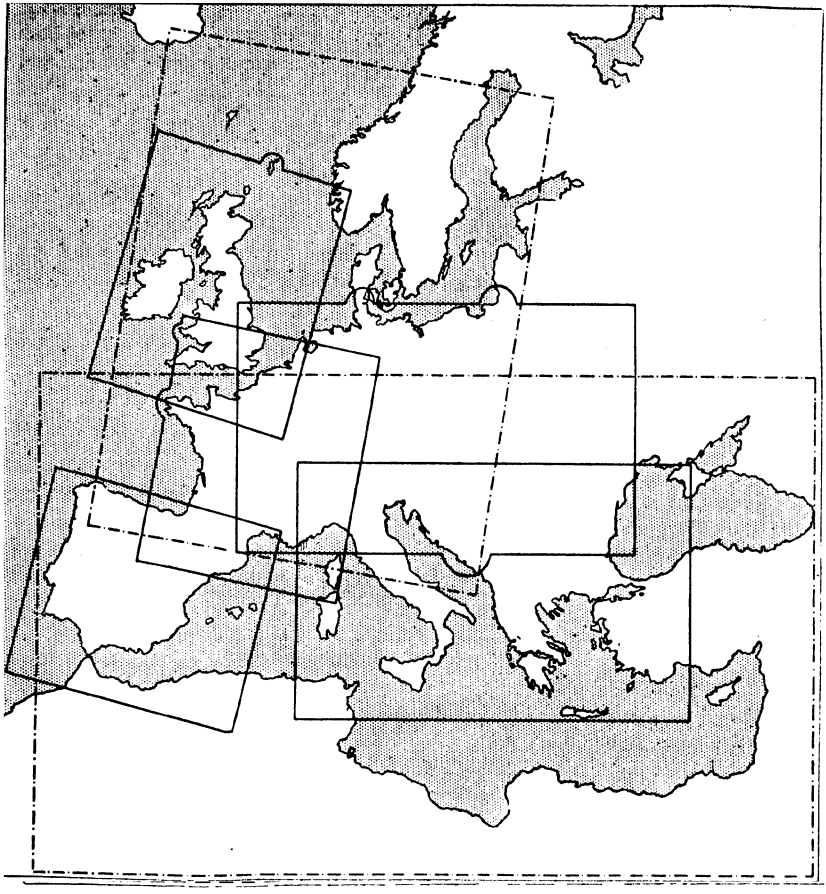
World Maps.

(1) Maps of a selected region, to exhibit scales, methods of showing relief, &c.
(2) Hemispheres, heights, depths: section along 45° N.
(3) Hemispheres, political: inset River Basins.
(4) Hemispheres, population, density: Races inset.
(5) Polar Regions: Land and Sea Hemispheres.
(6) Vegetation: Ocean Currents.
(7) Commercial Highways and Development.
(8) Temperature: January, July, Annual Range.
(9) Pressure and Winds, two or four months. Rainfall: seasonal.

Europe.

(10) Europe (20 millions), physical. Inset (40 millions); temperature: January, July.
(11) Europe (20 millions), political. Inset (40 millions); rainfall, seasonal.
(12) (*a*) Population, density; languages. (*b*) Minerals and manufacturing regions.

MAP Ia.



The European areas to be shown are enclosed by broken lines (Maps 13 and 17A) and continuous lines (Maps 14, 15, 17B, and 18).

(13) Mediterranean (10 millions).
(14) Central Europe (5 millions).
(15) Italy and Balkans (5 millions).
(16) Alps.
(17) (*a*) N.W. Europe (10 millions). (*b*) Spain (5 millions).
(18) (*a*) France (5 millions). (*b*) British Isles (5 millions).
(19) Large-scale maps; *e.g.*, position of Vienna.

America.

(20) (*a*) North America (40 millions), physical. Inset (80 millions); temperature: January, July.
(*b*) North America (40 millions), political. Inset (80 millions); rainfall, seasonal.

(21) (*a*) U.S.A. (20 millions). (*b*) Atlantic Coast (10 millions).
(22) Canada (20 millions), and Special Areas.
(23) South America (40 millions), political. South America (40 millions), physical.

Asia.

(24) Asia (40 millions), physical. Inset (80 millions); temperature: January, July.
(25) Asia (40 millions), political. Inset (80 millions); rainfall, seasonal.
(26) Southern Asia (20 millions).
(27) China and Japan (20 millions); Palestine.
(28) India, political (large scale); climate.

Australasia.

(29) (*a*) Oceania, including East Indies (40 millions), political. (*b*) Australia (20 millions), physical.
(30) (*a*) East Australia. (*b*) New Zealand, larger scale.

Africa.

(31) Africa, physical (40 millions). Political (40 millions).
(32) South Africa (20 or 12 millions). Insets, West Africa, Egypt, temperature, rainfall.

British Isles.

England and Wales, Scotland and Ireland, physical and political (2 millions).

Special regions, A, B, C, D, E, 1: 500,000.

Special regions, *a*, *b*, *c*, 1: 200,000.

It appears from our inquiries that there is a real demand for large-scale maps of special regions in the British Isles, which could best be met by special editions for different populous areas.

Junior School Atlas.

In a Junior School Atlas for each Continent one map (physical, with political boundaries shown in red) would meet all needs. Maps 4 and 5 would be combined; also 8 and 9 (temperature and rainfall only). For 26 and 27, India, China, and Japan (20 millions) might be substituted, and the following maps omitted, viz., 12, 15, 16, 17, 19, 21B, 22, 29A, and 30A, together with 18A if France were shown on Map 14.

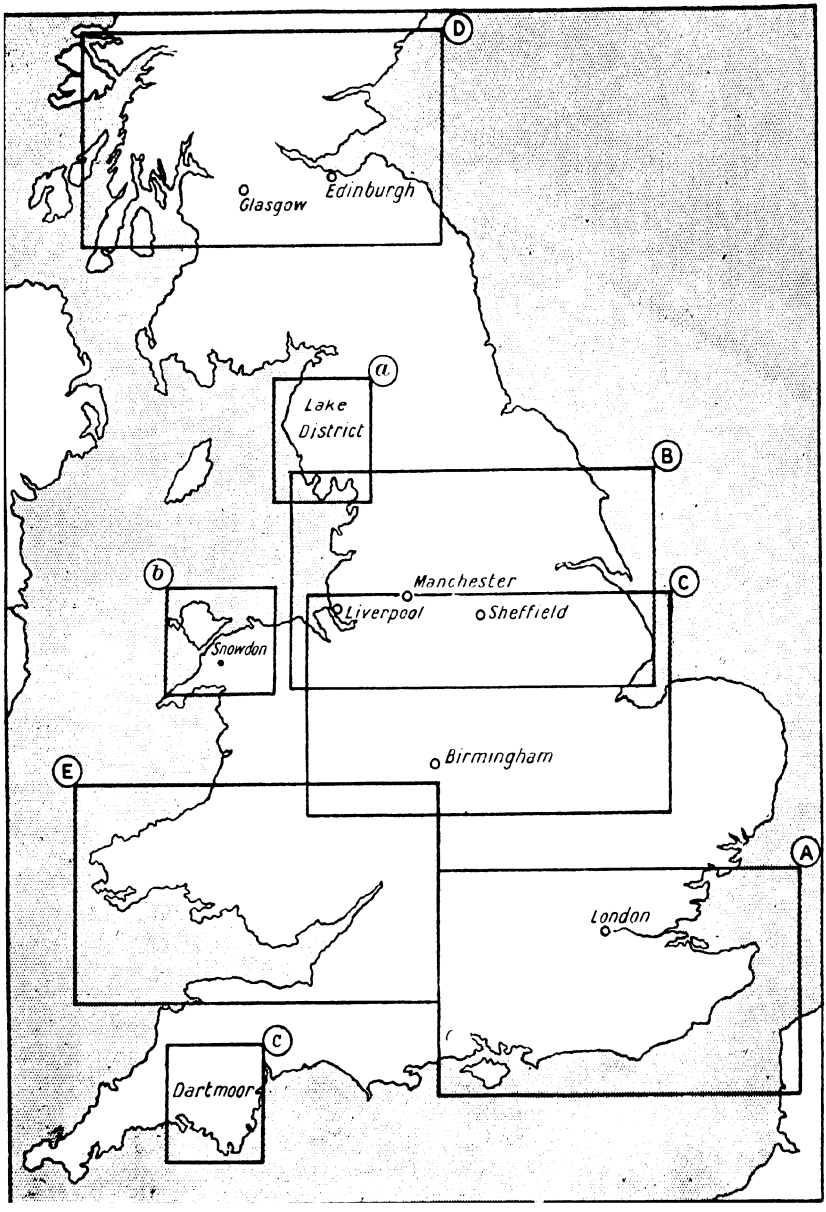
The Committee is unable to make any recommendation with reference to an Atlas for University use, feeling that a University student should have access to and familiarity with a wider variety of maps than could be included in one volume.

PART II.

Style and Draughtsmanship.

The chief criticisms of existing School Atlases are directed against excess of names, impurity of colour, and indistinctness of lettering.

MAP Ib.



A, B, C, D, E are areas, some of which might be shown by double page maps on a large scale (*e.g.*, 1 : 500,000); *a*, *b*, *c*, single-page maps of holiday areas on a still larger scale (say 1 : 200 000).

Most Atlases still err on the side of excess of names, though in some quarters there has been great improvement of late. The Atlas should be provided with a place index, giving latitude and longitude of important sites not named on the plates. This would enable the student to add the names which he requires for his own purposes, on a blank outline. The use of such blank maps has increased greatly in recent years, and it is desirable that a School Atlas should be so published that its maps may be obtained also singly, both fully coloured and also in outline.

Where both orographical and political maps of one region are provided, no names but those of physical features should appear on the orographical map. The maps should have as little as possible in common beyond the outline, rivers, and railways.

Colour.

The 'layer-system' is almost universally used for the expression of relief in School Atlases. Intermediate heights may be shown by conventionalised hachuring. Contours on such maps can give but little idea of form, and are not recommended except when required in printing, as to bound the colour bands. In nearly all the Atlases examined the colours were found to be too deep. The Committee confidently recommends that the colour-scheme adopted for the International Map 1 : 1,000,000 and based on the teaching of physiological optics be followed as closely as possible for all physical maps.

For the sea, deepening shades of blue should be used, not white, the depths being indicated in feet rather than in fathoms; for lakes, the same blue as for the shallowest sea. Rivers and river names should be in blue. Red lines which stand out well from the background can be used to show political frontiers on an orographical map. Colour indicating relief should not be interrupted at the frontiers but carried to the margin of the map.

Reference should be made to an article on 'Relief in Cartography' ('Geographical Journal,' March and April, 1914) by Captain (now Major) H. G. Lyons, D.Sc., F.R.S., to whom the Committee is indebted for much help and advice.

Gloss.

It is important that no glossy inks or super-calendered paper should be used for a School Atlas. The reflections from a glossy surface are apt to injure eyesight, partly by interfering with binocular vision. Maps, coloured or uncoloured, can be produced without extra expense on paper from which the specular reflection at 45 degrees does not exceed the diffuse reflection (see Section L, reports on 'The Influence of School Books upon Eyesight,' 1913 and 1915)

Lettering.

Four styles of lettering are used on the Maps II. and III. printed in this report: (*a*) The North-west quarter is entirely sans-serif except

for the names of States; (*b*) the South-west quarter is the ordinary Roman and italic with strong serif; (*c*) the North-east quarter is entirely Roman with the exception of water-names and the names of physical features (the principal point of comparison between (*b*) and (*c*) lies in the smallest town names, which in (*b*) are italic and in (*c*) Roman); (*d*) the South-east quarter is like (*a*) but entirely sans-serif. There are more names and the letters are smaller. With reference to size, Map II. shows letterings generally suitable for a Junior School Atlas, Map III. letterings generally suitable for a Senior School Atlas. The smallest type (in the South-east quarter) is in each case too small for use in the appropriate Atlas. With reference to style, for the larger sizes the best style is one approaching sans-serif. The italic when used for the larger sizes, or with too frequent distribution in any size, is apt to produce a dazzling effect. On the other hand, italic by its obliquity gives a larger letter for a given height, and this increase of size is particularly advantageous with smaller names; it also affords a useful model for students to copy in manuscript. A sparing use of italic for small names is therefore recommended, together with a sans-serif style for all permissible sizes.

Note.—The maps are published for purposes of illustration only. They are in no respect models, nor has the Committee dealt with the orthography of names.

Projections.

Few varieties of projection should be employed in a School Atlas. For Hemispheres, Clark's Minimum Error Projection is best; the Globular Projection is to be avoided. For Continents and for the larger countries, Zenithal Equal Area; for the smaller countries a simple conical development. The excessive distortion of Mollweide's Homolographic Projection makes it unsuitable for school use. From the body of the Atlas, Mercator's Projection should be excluded; it can, however, be effectively employed as an Index Sheet. It is an excellent lesson in distortion to plot carefully on a Mercator's Projection the areas covered by the individual maps of the Atlas. We consider that Hemisphere maps should be much more freely employed, since they are the most accurate representations (except the globe) of the Earth's surface. Where practicable, they should be used to exhibit world distributions of all kinds. It has been stated already that the scales employed should be few and as a rule simple multiples one of another. On each map the scale should be clearly stated. In the margin should be indicated other towns in the same latitude and also (on maps of wide extent) the area of a quadrilateral of the network.

It will be noted that the projection in Maps II. and III. has been divided into two halves. The Western half shows a map bounded by meridians and parallels. Its advantages are evident, and it is suggested that the map of Europe should be bounded in this way, to serve as a warning that a vertical line on the map does not necessarily run North and South. The utility of carefully designed insets occupying the margin far outweighs any distraction which they may cause to the eye.

Conventional Signs.

In general, conventional signs should not be multiplied or created *ad hoc*. The few recognised signs are sufficient, unless to indicate any new feature, such as a first-class wireless telegraphy station, or the employment of river water for power or irrigation. The limit of navigation on a river may well be shown by an anchor. The solid black dot for town sites has advantages over the fine open circle, as better revealing concentration of urban population. Larger towns require a larger dot or a dot within a circle. Railways and canals should be shown by single lines of a distinctive character; a fine single black line should be avoided. On large-scale maps a symbol is required for roads also, since motor traffic has restored their significance.

Words or conventional signs indicating the distribution of economic production are strongly deprecated. If economic factors must be exhibited on a general map, solid colour or shading should be used to show the concentration of industrial population, or the locality of high production of two or three commodities of first importance.

Black and white maps in school books (textual maps) should not attempt to supersede Atlas maps, but should be confined to their function of illustrating statements in the text. Mechanical shading is often either too coarse or too light. The use of large areas of solid black should be cautiously exercised. White letters on a black ground, and black letters on a shaded area, too often tend to print obscurely. The size of type, if intended to be read, should be as carefully considered as in the Atlas, and additional allowance should be made for imperfection in reproduction. Over-reduction in the camera from the original drawing is one of the commonest faults in block-maps, and owing to limitations imposed by the size of the page, the fault lies usually in the drawing. In general a textual map must be simple and not attempt to show high detail, and features tending to mutual obscuration should not be shown on the same map. Thus the same phenomenon for different seasons or associated phenomena (*e q* , isotherms for January and July, or isotherms and isohyets) should not be shown on the same map—the particular examples cited apply equally to coloured maps. But this rule is not rigid. It is sometimes difficult to compare the phenomena shown on two maps (*e.g.*, the climatic and the form divisions of a large country) when the two might have been exhibited on the same map without obscurity.

Wall Maps.

The recommendations of the Committee in regard to the style of a School Atlas apply almost without modification to wall maps.

The scales employed should be as few as possible, and should be simple multiples of each other. This is more easily arranged in a set of wall maps than in an Atlas, because there is here no necessity that the maps should be of uniform size, or that the amount of margin should be uniform throughout the series. For the same reason, it is far less necessary that the map area should be foursquare, especially in maps of continents and oceans, where every effort should be made to emphasise the fact that the objects represented lie upon a spheroidal surface. Awkward blank areas in the margin, which would be dis-

tressing in an Atlas-page, are invaluable for supplementary letterpress in a wall map; though they should never be so far filled up as to prevent the map itself from standing out boldly on the sheet.

The far larger scale of a wall map is no excuse for the introduction of minute detail or a crowd of names. A wall map is essentially a diagram. The use of wall maps without names, or with only a few names or initials appended to town-dots or the mouths of rivers, is greatly to be encouraged. Some French wall maps are printed in duplicate, back to back, with the names on one side, and the physical features and town-dots, unnamed, on the other.

Even more than in the Atlas, colour shows relief better than contours. Inclined illumination from the North-west gives, in skilful hands, an almost pictorial effect. The colours of a wall map should not, however, be too bright or deep, with the single exception of the scarlet which is appropriately used for all kinds of arbitrary lines.

Wall maps are often too elaborate and costly. The paper must, however, be good enough to stand occasional cleaning with breadcrumb or soft indiarubber. The use of inferior paper has led to the current practice of varnishing the surface. Varnish has fatal effects upon a map. The reflected light from the surface makes the map useless to a large class in a well-lighted room and actually diminishes the amount of light from the printed and coloured surface below. There are very few kinds of varnish in use which do not turn brown or yellow with age.

It should always be remembered that the wall map is intended to supplement, but not to replace, the Atlas. Most wall maps fail by attempting too much.

Gaseous Explosions.—Interim Report of the Committee, consisting of Dr. DUGALD CLERK (*Chairman*), Professor DALBY (*Secretary*), *and* Professors W. A. BONE, F. W. BURSTALL, H. L. CALLENDAR, E. G. COKER, *and* H. B. DIXON, Drs. R. T. GLAZEBROOK *and* J. A. HARKER, Colonel H. C. L. HOLDEN, Professors B. HOPKINSON *and* J. E. PETAVEL, Captain H. RIALL SANKEY, Professors A. SMITHELLS *and* W. WATSON, Mr. D. L. CHAPMAN, *and* Mr. H. E. WIMPERIS.

OWING to the war, the completion of the equipment of the new laboratories of the Imperial College of Science and Technology, already referred to in the previous report, has been seriously delayed, and the investigation of many problems of importance has had to be postponed. Also, many of the members have been engaged on work for the Government, so that researches on questions under consideration have been either prevented or interrupted. It is not possible, therefore, to present a report to the Association this year. The general work of the Committee, however, has gone on; and during the session three meetings were held at the City and Guilds (Engineering) College, at which the following Notes were presented and discussed:—

Note 36, by Dr. HARKER, on 'A Method for the Determination of the Specific Heat of the Working Fluid of a Gas Engine at High Temperatures.'

Note 37, by Mr. E. GRIFFITHS and Dr. J. A. HARKER, on 'A Method for the Determination of the Specific Heat of Gases at High Temperatures.'

Note 38, by Dr. WATSON, on 'The Variation of the Mean Temperature of the Cylinder Contents with the Change of Fuel-Air Ratio for an Engine using Petrol, Benzol, and Alcohol.'

Note 36.—At the first meeting of the Committee this session there was some discussion on the problem of the determination of the specific heat at high temperatures of the working fluid of the gas engine by some more direct and, if possible, more continuous method than those hitherto employed by members of the Committee, and the object of the Note was to suggest a method which might fulfil these requirements.

Note 37 deals with this problem also, and describes a method which has been roughly tested by the authors and which appears to have important possibilities.

Note 38 is an account of an investigation on temperatures reached in the cylinder of a small high-speed four-cycle engine using different fuels, accompanied by a figure giving the results of the experiments.

The Committee recommend that they be again reappointed, and ask that a sum of 50*l.* be granted to them for the ensuing session.

Stress Distributions in Engineering Materials.—Report of the Committee, consisting of Professor J. PERRY (*Chairman*), Professors E. G. COKER *and* J. E. PETAVEL (*Secretaries*), Professor A. BARR, Dr. C. CHREE, Mr. GILBERT COOK, Professor W. E. DALBY, Sir J. A. EWING, Professor L. N. G. FILON, Messrs. A. R. FULTON *and* J. J. GUEST, Professors J. B. HENDERSON, F. C. LEA, *and* A. E. H. LOVE, Mr. W. MASON, Sir ANDREW NOBLE, Dr. F. ROGERS, Mr. W. A. SCOBLE, Dr. T. E. STANTON, Mr. C. E. STROMEYER, *and* Mr. J. S. WILSON, *to report on certain of the more Complex Stress Distributions in Engineering Materials.*

THE Report presented at the Australian Meeting of the British Association called attention to the desirability of obtaining complete and systematic data with regard to three definite materials—namely, a mild steel, an axle steel (carbon 0·3 per cent.), and a nickel steel alloy. The Committee obtained a stock of one ton of mild steel early in 1914, but owing to the outbreak of war further supplies of the other materials are not yet available. The physical properties of the mild steel now in the possession of the Committee have been the subject of several investigations, and a chemical analysis made at the National Physical Laboratory has been furnished by Dr. Stanton as follows:

C=0·132 per cent.
Si=0·028 „
S=0·017 „
P=0·028 „
Mn=0·300 „

The material, which is from a single melting, shows the influence of the subsequent rolling as may be observed from some preliminary tensile tests furnished by Mr. Cook, Table I.

Tensile Tests of B.A. Mild Steel as received from the makers.

TABLE I.

Nominal diameter of bars, inches	$\frac{9}{16}$	$\frac{13}{16}$	$1\frac{1}{16}$	$1\frac{5}{16}$
Actual diameters of bars, inches	·385 machined	·811	1·068	1·324
Yield stress in tons per square inch.	23·95	19·35	15·80	13·40
Maximum stress in tons per square inch	26·40	24·40	23·40	22·40
Percentage elongation on 8 inches	22·2 on 6 in.	33·5	33 7	37·6
Percentage elongation on 2 inches	27·5	55 0	58·5	66·5
Percentage contraction of fracture	69·8	69 8	65·6	66·2

Professor Dalby has also investigated the properties of a specimen of this steel, cut from a rod $1\frac{1}{8}$ in. diameter, with an apparatus[1] in which the load and extension are recorded automatically upon a photographic plate. The diagram so obtained is shown in fig. 1, together with the numerical results of the test.

Table of Data.

Original diameter of specimen	0·564 in.	Area = 0 25 sq. in.
Diameter at fracture	0·324 in.	Area = 0·0825 ,,
Stress at yield point		= 18 tons per sq in.
Ultimate stress reckoned on original section		= 24 8 ,,
Actual stress of fracture		= 53 8 ,,
Percentage reduction of area		= 67·4
Distance between gauge points		= 5·00 in.
Extension on length of 5 in.		= 1·53 in.
Elongation on length of 5 in.		= 30·6 per cent.
Corresponding elongation for a standard length of 10 diameters = 5·64 in.		= 29·7 per cent.
Young's Modulus (E) in pound and inch units.		= $30{\cdot}3 \times 10^6$

Photomicrographs made by Professor Dalby and Dr. B. P. Haigh show that the structure is of a usual type for steel of this composition. The experiments prove that the influence of rolling is considerable and that comparable results cannot be obtained without annealing by some standard method which will bring the material to a uniform molecular structure for all sizes of bars.

It has been suggested that the bars should be heated at a temperature of 900° C., and cooled in the air. Mr. W. A. Scoble has made an investigation of one of the sizes of bars after heating to 900° C. in an electric furnace, and allowing them to cool in position. An account of his results is given in Appendix A.

An investigation of the effects of alternating stress has also been made by Dr. B. P. Haigh and is described in Appendix B.

[1] An optical load-extension indicator, together with some diagrams obtained therewith. *Proc. R. S.* 1912. Load-extension diagrams taken with the optical load-extension indicator. *Proc. R. S.* 1913.

Dr. F. C. Lea and Mr. C. E. Stromeyer have joined the Committee during the year.

The Committee ask to be reappointed, with a grant of 100*l.*

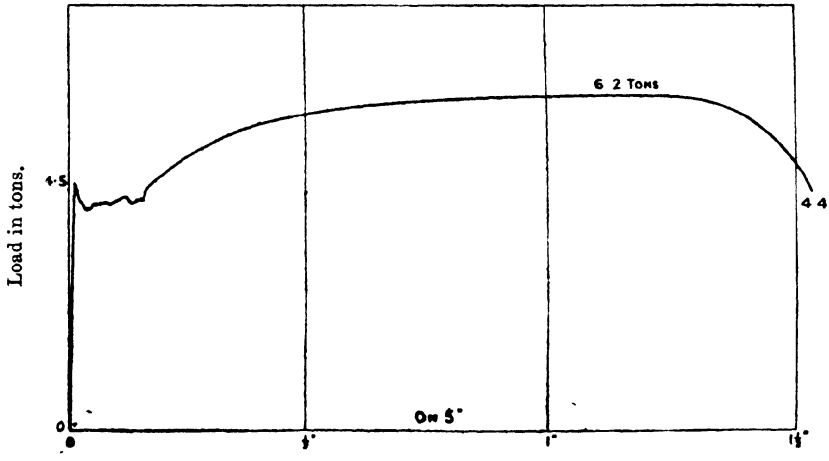
Appendix A.

Report on Static Tests of a Mild Steel received from the British Association Stress Committee.

By Mr. W. A. Scoble.

The preliminary tensile tests made by Mr. Cook showed that the yield stress varied from 23·95 tons per square inch for the $\frac{9}{16}$ bar

Fig. 1.



to 13·40 tons per square inch for the $1\frac{5}{8}$-inch bar. To compare the results of static tests on the different bars it was clear they should be brought to a uniform condition, or the advantage of having them of the same steel would be neutralised. At this time the question of annealing had not been raised, but the specimens for which the test results are given below were all subjected to the following treatment. The specimens were cut from a $\frac{13}{16}$-inch round bar, placed in an electric furnace and heated with the furnace to a temperature of about 900° C. The bars were allowed to cool inside the furnace.

Tension Test.—The specimen had screwed ends and was turned down to 0·499-inch diameter. There was a very slight indication that the strain increased more rapidly than the stress. The extensometer used was of special design, and the measurement of elongation was certainly correct to within 0·5 per cent.

Yield stress	10·04 tons per sq. inch.
Maximum stress	20·89 „ „ „
Elongation on 5 inches (10 diameters) .	36 per cent.
Reduction in area at fracture . . .	69·6 per cent.
'E' 28,800,000 lbs. or 12,850 tons per sq. inch.	

Bending Test.—The specimen was turned to 0·4365-inch diameter and subjected to a uniform bending moment. The deflection was measured on a length of 4 inches by a sensitive piece of apparatus supported on the specimen.

Bending moment at first yield . .	168 lbs.-inches.
Maximum stress „ „ . .	9·18 tons per sq. inch.
Final bending moment . . .	260 lbs.-inches.
Stress, assumed uniform over section	8·37 tons per sq. inch.
"E" from straight portion of curve	30,400,000 lbs. per sq. inch.
	13,900 tons per sq. inch.

Torsion Tests.—The diameter of the test piece was 0·4367 inch, and the twist was measured on a length of 4·47 inches. A torque-twist

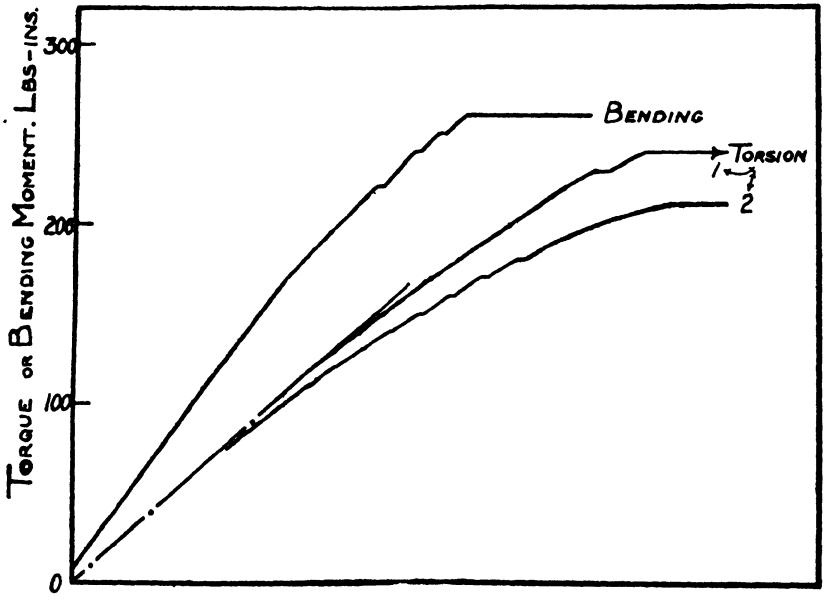


FIG. 2.

curve is given in fig. 2. The curve deviates from the straight line at a torque of about 120 lbs.-inches (3·27 tons per square inch) and complete yield takes place at 240 lbs.-inches (5·31 tons per square inch on the assumption of uniform stress distribution).

This result was considered to be unsatisfactory, and another torsion test was made on the specimen which had already yielded slightly by bending. There appeared to be no straight line portion to the torque-twist curve, a time effect was measured at 110 lbs.-inches (3·0 tons per square inch), and final yield took place at 210 lbs.-inches (4·65 tons per square inch on the assumption of uniform stress distribution).

These results present certain difficulties. The tension test was satisfactory and the data obtained are what would be expected from the grade of steel and from the tests made by Mr. Cook. The

elastic limit and yield point appeared to coincide at a stress of 10 tons per square inch. Judged by the first yield the steel is weaker under a bending load (9·18 tons per square inch), but the point is clearly defined on a carefully plotted load-deflection diagram. There was a considerable creep when the skin stress would be 12 tons per square inch, assuming Hooke's Law to hold. The final stress was evidently between 14·2 (Hooke's Law) and 8·37 tons per square inch (uniform distribution), and it appears that 9·2 tons per square inch is very approximately correct for the yield point stress by bending. The torsion results deserve special notice. The first yield apparently took place at 3·27 tons per square inch skin shear stress, and the test piece gave way and was twisting slowly but continuously when the skin stress was between 6·54 (Hooke's Law) and 5·31 tons per square inch (uniform distribution). The stress difference at first yield appears to be much less in torsion than under bending or tension, but the flow stress difference for torsion is greater than for tension, and probably also greater than for bending. It appeared probable that the point on the torque-twist curve where the straight portion ends was not the point at which yield occurs, possibly because strain was not proportional to stress even when the material was elastic, but such an assumption is confused by the fact that strain was never proportional to stress in the second torsion test. In the latter case it is impossible to locate a yield point, but the final flow shear stress was between 5·71 (Hooke's Law) and 4·65 tons per square inch (uniform distribution), a result which gives a stress difference in good agreement with that from the tension test.

Appendix B.

Report on Alternating Stress Tests of a Sample of Mild Steel received from the British Association Stress Committee.

By Dr. B. P. Haigh.

The material supplied was in the form of $\frac{9}{16}$-inch rolled bar, and was described as 'dead-mild': its tensile strength was approximately 26 tons per square inch, with an elongation of about 21 per cent. on an 8-inch specimen, $\frac{3}{8}$ inch in diameter. The results of two tensile tests are given below, column A giving the figures obtained in a preliminary test made by Mr. Cook, and column B those in a very slow test, lasting over 30 minutes, made at Greenwich:—

	A	B
Diameter of specimen (turned)	0·385	0·374
Yield stress, tons sq. in.	23·95	21·0
Maximum stress, ditto	26·4	25·2
Elongation, per cent.	22·2 on 6 in.	20·5 on 8 in.
Reduction of area at fracture, per cent. . .	69·8	71·4

A Brinell test, in which a standard 10 mm. ball was pressed upon a longitudinal section of the bar, with the standard load of 3,000 kg. gave an impression having a diameter of 5·78 mm., indicating a 'hardness number' of 104 kg./sq. mm., equivalent to 66 tons per square inch. The

ratio between the maximum stress of the tensile test and the hardness is 0·40 to 0·38, according to the value taken for the tensile test. The specimens used in the tests which are now described were not annealed, but were tested in the condition in which the metal was received.

Alternating stress tests were carried out in a machine of the type described at the Dundee Meeting of the Association, 1912.[2] In this machine the alternating stress applied to the specimen is obtained by combining two pulsating forces (derived from two-phase magnets) acting upon opposite sides of a single armature to which one end of the specimen is rigidly coupled. The inertia force required for the oscillatory acceleration of the armature is cancelled by the force of deflection of a spring which is adjusted to suit the frequency of the test. The load applied to the specimen is determined by measuring the voltage induced in a fine wire secondary coil, wound close to the pole faces of the magnets. To standardise the machine, a phosphor-bronze specimen, fitted with an extensometer, and previously tested under steady stress, is inserted in the machine and stressed by the application of an assigned voltage at the desired frequency. The range of extension measured under alternating stress may be used as the basis of measurement, or, alternatively, the alternating stress may be converted to a steady stress by reversing the pull of one of the two magnets. Stroboscopic observations showed that the stress applied to the specimen varies very approximately in a sine wave, and it is estimated that the load range of stress can be determined with an accuracy within 1 per cent. Combinations of alternating and steady stress are obtained by extending or compressing the spring used for compensating the inertia of the armature. The stiffness of this spring having been measured, the magnitude of the steady stress is determined by measurement of the deflection of the spring.

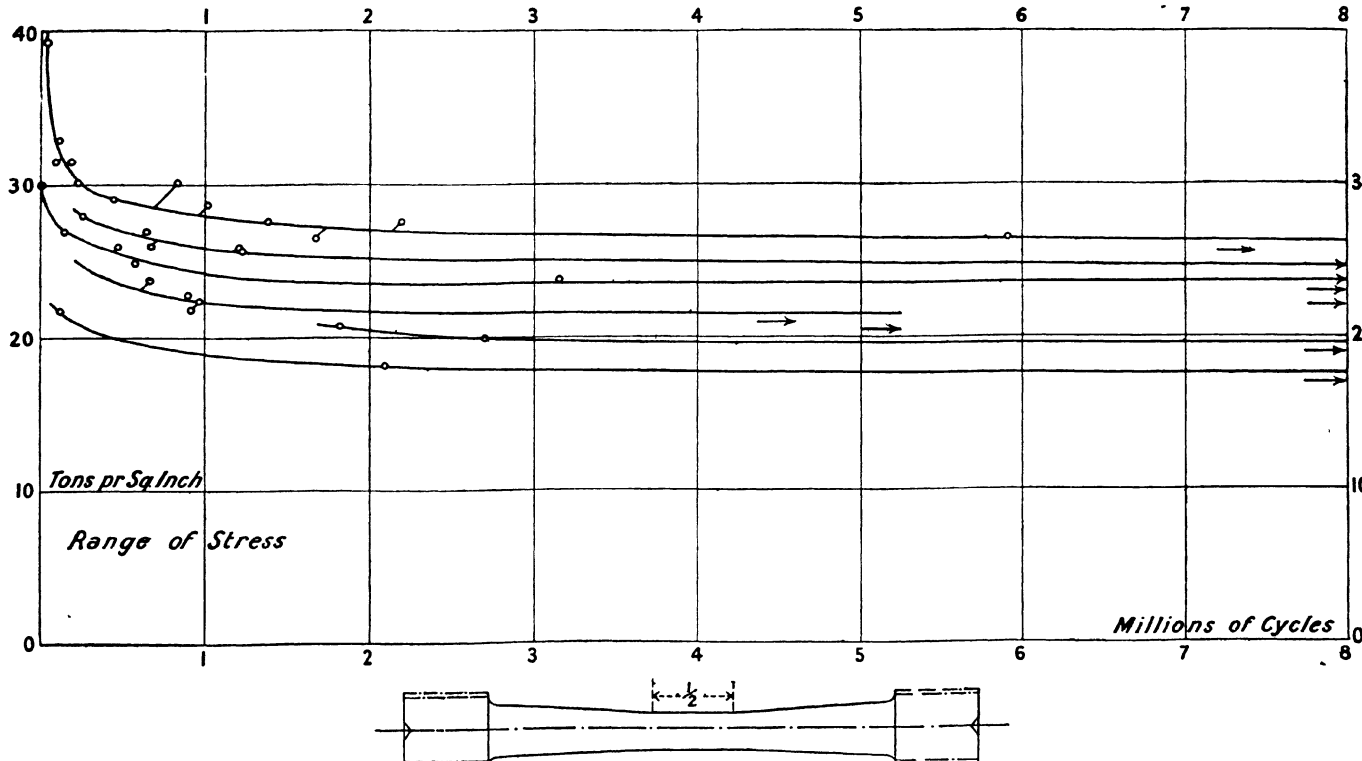
The form of the specimens used in the alternating stress tests is shown in Fig. 3. The maximum stress is developed in the central cylindrical portion of the piece, about $\frac{1}{2}$ inch in length, which is joined to the conical ends by gradual transition curves. The ends of the specimens are screwed, and the necessary precautions are taken to ensure that the test-pieces are free from initial stresses, either torsion or bending, due to the tightening of the grips.

The tests may be arranged in seven series, and are summarised in the table given below. In the first series the stress alternated between equal intensities of tension and compression. In three series, II. to IV., steady stresses of tension were applied in combination with the alternating stress, and in the final three series, V. to VII., steady stresses of compression were combined with the alternating stress. The frequency of stress employed was the same in all series—viz., 2,000 per minute. The duration of the tests followed by fracture varied from a very few cycles up to 8 million. Other tests were continued beyond this number, in one instance to seventeen million cycles, without fracture.

In Fig. 3 the range of stress is plotted on a base representing the

[2] See also *Engineering*, November 22, 1912.

FIG. 3



Form of Specimen.

Series	Steady component Tons/sq. in.	Range of stress Tons/sq. in.	Millions of cycles to fracture
I.	Nil	57·2	Approx. Nil
		51·2	Specimens became
		48·2	very hot
		39·3	0·003
		32·7	0·08
		31·3	0·056
		31·3	0·16
		29·9	0·19
		29·9	0·80
		28·8	0·41
		28·7	1·01
		27·5	1·37
		27 5	2·18
		26·4	1·66
		26·4	5·9
		25·4	unbroken after 7·2
II.	4·95	27·9	0·24
		26·8	0·64
		25·8	0·66
		25·8	1·20
		25·7	1·22
		24·7	unbroken after 8·1
		23·7	do. do. 17·0
III.	9·87	28·9	Approx. Nil.
		25·8	do.
		25·3	do.
		23·7	0·67
		22·7	0·89
		22·3	0·96
		21·7	0·91
		21·2	unbroken after 4·6
		20·7	do. do. 5·1
IV.	12 8	21·7	0·11
		18·1	2·08
		17·3	unbroken after 8·62
		16·5	do. do. 14·1
V.	−5·21	30·0	Nil
		26·8	0·13
		25·8	0·96
		24·8	1·06
		23·7	3·14
		23·7	unbroken after 8·4
		22·7	do. do. 8·0
VI.	−9·35	23·7	0·19
		22·7	4·60
		21·8	8·66
VII.	−12·2	20·8	1·81
		19·8	2·69
		19·0	unbroken after 8·36

numbers of cycles endured. It is clear that each series of experiments indicates a limiting range of stress below which the endurance increases with very great rapidity. It may be doubted whether even the longest tests indicate an absolute fatigue limit, but the asymptotes are at least sufficiently clear to indicate a fairly definite value. These values are summarised for the several series in the following table:

Series	Steady stress Tons per sq in	Limiting range of alternating stress Tons per sq. in.
I.	Nil	26·0
II.	4·95	24·5
III.	9·87	21·5
IV.	12·80	17·5
V.	−5·21	23·5
VI.	−9·35	21·5
VII.	−12·20	19·5

In Fig. 4, curve F, the limiting range of stress is plotted as a function of the steady stress applied to the specimen. It is interesting to note that, especially for the tension side of the diagram, the form of

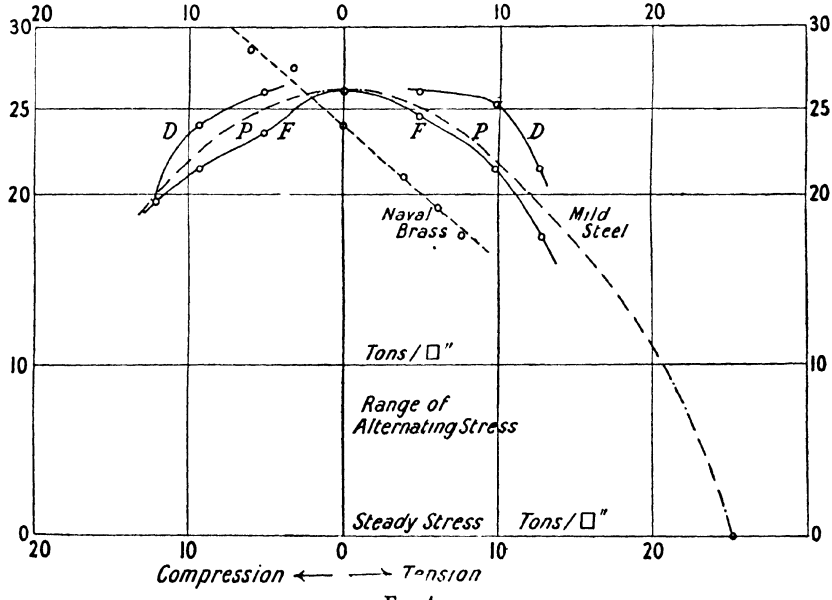


Fig. 4.

the curve is approximately in accordance with the hypothesis expressed by 'Gerber's parabola.'[1] Thus the results of the tests with combined alternating and steady stresses may be expressed by the formula

$$f_{max}=\Delta/2+\sqrt{f^2-n\Delta f} \quad \text{or}$$
$$f_s^2=f^2-n\Delta f$$

[1] See Unwin's *Testing of Materials of Construction*, p. 388, 3rd edition.

where

f_{max} is the maximum permissible combined stress
f_s being the steady component of stress and
Δ being the range of variation.
f is the ultimate strength of the metal
and n the ratio between f and Δ (=approximately unity for this metal), the stresses being in tons per sq. in.

On the left hand side of the diagram, Fig. 4, representing the results obtained with combinations of alternating and compressive stresses, the curve deviates noticeably from the parabolic form. The

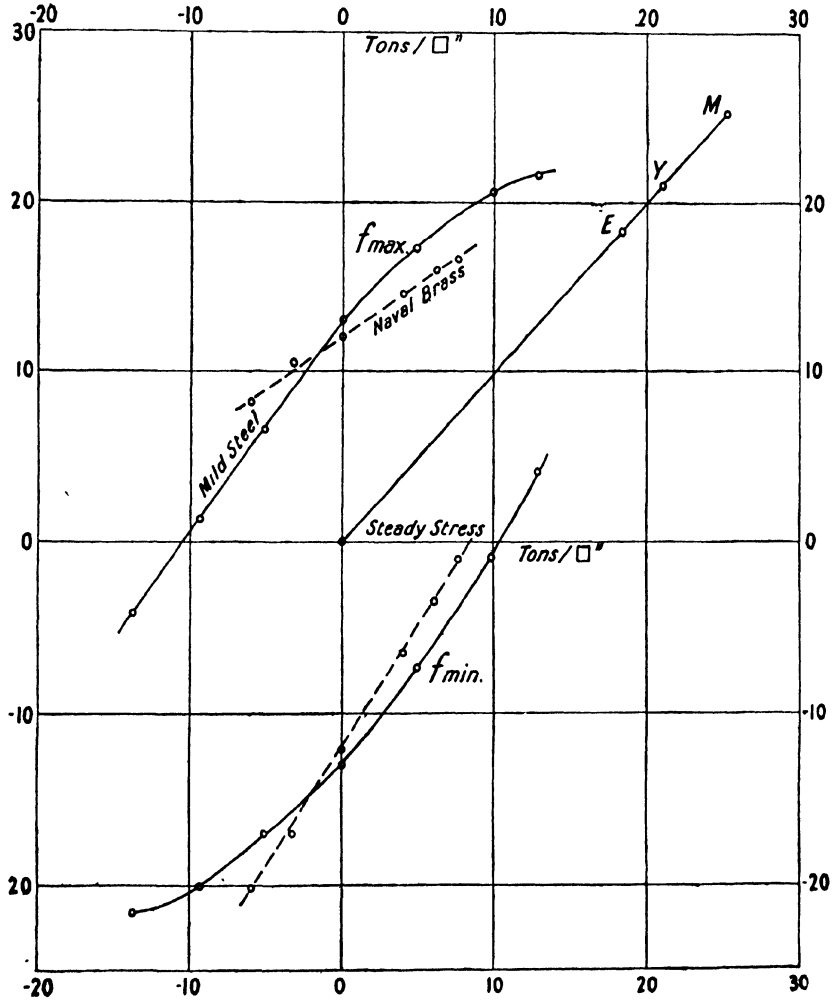


FIG. 6.

Specimen A Specimen B.

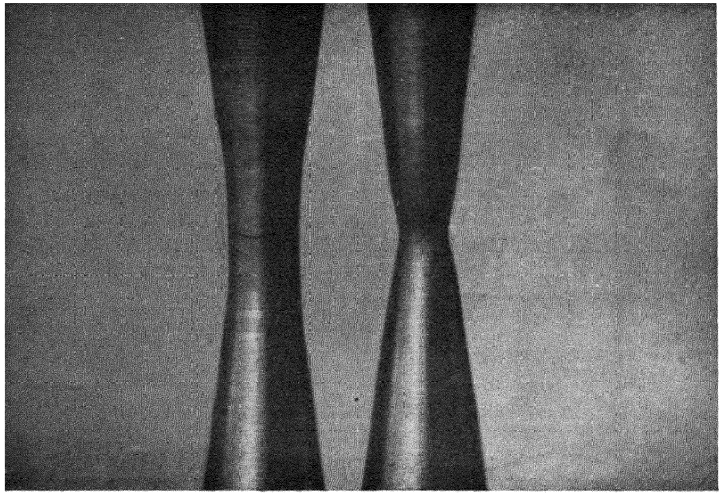


FIG. 5.

A.—Fractured after 672,000 cycles. Range of stress 23·7 tons per square inch combined with steady tension of 9·87 tons per square inch.
B.—Extended immediately with the same stress of steady tension when range of stress reached 29 0 tons per square inch.

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[*To face p.* 169

discrepancy is greatest with moderate loads and disappears when the magnitude of the steady stress is increased. At this stage, however, the metal is liable to yield in a ductile manner owing to the intensity of the steady stress, so that it is hardly practicable (or profitable) to continue the investigation with higher stresses.

Fig. 4 shows also, by the curve D, a limiting range of stress beyond which ductile failure occurs instead of the characteristic fatigue failure. The exact position of the curve is difficult of determination, as the range of stress necessary to produce ductile extension depends on the rate of increase of stress in somewhat the same manner as the form of the stress-strain diagram depends on the rate of application of load. Thus fatigue appears to play a part in ductile extension as well as in brittle fracture, accelerating the development of strain.

The two specimens shown in Fig. 5 clearly illustrate the two manners of failure. Thus specimen A fractured after 672,000 repetitions of a cycle of stress in which an alternating stress having a range of 23·7 tons per square inch was combined with a steady stress of 9 87 tons per square inch. Specimen B, loaded with the same component of steady stress, extended immediately with reduction of cross sectional area, when the range of alternating stress reached the value of 29 tons per square inch. Ductile failures occurred at lower ranges than this when time was given for the phenomenon to develop, thus the curve D is drawn through the ordinate at 25·2 tons per square inch range, no cases of ductile extension having been met with below this limit. On the compression side of the diagram the curve D falls so low that it intersects the curve F. Thus in the series of experiments made with a compressive stress of 12 2 tons per square inch, all the specimens failed in a ductile manner, some showing signs of cracks while others simply settled down suddenly without visible cracks. It is remarkable that the zone between the two curves F and D is no wider than is shown in the diagram.

In Fig. 6 the maximum and minimum values of the stresses producing fatigue fracture are plotted on a base representing the steady component of the stress-producing fatigue. The elastic limit, yield stress, and maximum strength of the metal are represented by the points E, Y, and M on the line OM, passing through the origin and inclined at 45° to the axes. The full lines show the loci of the maximum and minimum stresses for the B.A. mild steel, while the dotted lines indicate, for the sake of comparison only, the corresponding results obtained with a sample of Naval Brass. (A dotted line in Fig. 4 likewise indicates the same results for Naval Brass.) The striking difference between the forms of the loci indicates that a great deal of experimental work with different metals is still required before any general theory can be evolved.

As indicated in the table which follows, the ratio between the semi-range of the limiting fatigue stress (with equal intensities of tension and compression) and the maximum strength of the metal is approximately 0·51. In other mild steels tested by the writer, the value of this ratio has varied between 0·5 and 0·6, the lower value being met with in annealed metal and the higher in cold-strained specimens.

In structural steels containing higher percentages of carbon and possessing higher ultimate strengths, the value of the ratio falls to about 0·40.

Elastic limit	= 18·3	0·726
Yield stress	= 21·0	0·833
Maximum stress	= 25·2	= unity
Semi-range of limiting alternating fatigue stress	= 13·0	0·515
Range of limiting pulsating fatigue stress, tension	= 21·0	0·833
Brinell hardness	= 66·0	2·62

The Lake Villages in the Neighbourhood of Glastonbury.—Report of the Committee, consisting of Professor W. BOYD DAWKINS (*Chairman*), Mr. WILLOUGHBY GARDNER (*Secretary*), Professor W. RIDGEWAY, Sir ARTHUR J. EVANS, Sir C. HERCULES READ, Mr. H. BALFOUR, *and* Mr. A. BULLEID, *appointed to investigate the Lake Villages in the Neighbourhood of Glastonbury in connection with a Committee of the Somersetshire Archæological and Natural History Society.* (*Drawn up by* Mr. ARTHUR BULLEID *and* Mr. H. ST. GEORGE GRAY, *the Directors of the Excavations.*)

THE second part of the fifth season's exploration of the Meare Lake Village by the Somersetshire Archæological and Natural History Society began on September 21, 1914, and continued until October 3. The ground excavated was situated in the same field and was continuous with the work of previous years. The entire area occupied by the dwelling-sites in Field IV. has now been explored, with the exception of the ground covered by the shed and a space of three feet around it. When work is resumed it is proposed to move the shed into Field V. and complete Field IV. at the same time as the exploration of Field V. is proceeding.

The digging of last autumn included the examination of portions of Mounds IX. and XII., and of the whole of Mounds XVI. and XX. Nothing of marked importance structurally was found in or about Mounds XII., XVI., and XX., but the under-mentioned points of interest were discovered in Mound IX. The upper part of the mound was denuded, and when looked at in section the clay floors appeared arranged in layers, rainbow-fashion. The summit of the arch down to the depth of the sixth floor was missing, and looked as if it had been washed or cut across horizontally before the flood-soil had been deposited. This mound contained, amongst other things, a very remarkable and complete series of superimposed hearths, nineteen in all, and a nearly complete circle of flat split oak wall-posts accompanied by wattle-work.

During the examination sectional and other plans, as well as photographs, were made of the most interesting and important features, as is customary.

In May, after the last Report was sent in, the excavation of Dwelling mounds XVIII. and XIX. was completed, but nothing of structural importance was noted.

The Relics.

Amber.—About one-quarter of a large orange-coloured clouded amber ring (A 3), which, when perfect, was 40 mm. in diameter.

Bone Objects.—Perhaps the most interesting objects of bone found in the last excavations at Meare are the three pieces of worked *scapulæ* (B 81, 86 and 87). The heads and longitudinal spines have been cut down considerably, and little remains of the flat parts of the bone which have been intentionally removed. Two of these objects are perforated at the head. All of them are ornamented on the upper surfaces, (*a*) with two long rows of large dots and circles; (*b*) with transverse incised lines; and (*c*) with rows of circular depressions 3 mm. in diameter. A *scapula* of sheep, perforated at the head, was also found.

Among the other specimens is a long needle (B 90), with a lop-sided eye countersunk on one side; a smooth and tooled rib-bone (B 82), rounded off at one end, and having two perforations at the other; another perforated rib-bone (B 84); a polished metacarpus of ox (B 88); an awl in fine condition (B 80); a perforated radius of sheep (B 85); and some miscellaneous and, for the most part, incomplete implements connected with weaving.

Crucibles.—Two fragments of the usual type.

Baked Clay.—Ball of clay with a hole which does not penetrate through. A few sling-bullets and fragments of loom-weights.

White Metal.—A wheel-shaped disc, or amulet (Y 2), of white metal;[1] external diameter 25·7 mm.; weight 53 grains. This open-work object consists of a ring, or wheel, with four curved spokes (each pair forming an ogee curve); it is ribbed all over on both sides. Déchelette, in 'Manuel d'Archéologie Préhistorique Celtique et Gallo-Romaine,' 1914, figures very similar rings (*rouelles*) having diameters of from 25 to 50 mm. They are common in the La Tène stations; some of the 'wheels' have straight spokes (sometimes only four in number); and some of them are ornamented round the outer edge by cogged notches. They have been found in Marne and Bohemia attached to fibulæ—either fixed to the back of the brooch by means of a small chain, or merely looped on to the bow (see Déchelette, illustration, p. 1298). He has figured similar pendants belonging to the Bronze Age.

Bronze.—The two fibulæ found last September are of considerable interest, one being of the earliest type, the other of the latest type found in the Lake Villages.

(EE 9). Fibula of La Tène I. type[2]—one of some forty examples of this type so far recorded as having been found in Britain. The specimen is 54·5 mm. in length from the head of the bow to the nose, but the brooch is not complete and the coil is broken. It resembles in outline the longest brooch of this type (86 mm.) found in Britain—viz., that discovered on Ham Hill, Somerset, in 1912 (Taunton Museum).[3] The Meare specimen is of a somewhat attenuated form,

[1] At first it was thought to be of silver, but has since been tested. This is the only specimen of white metal found in the Lake Villages.

[2] Two brooches of La Tène II. type were found at Glastonbury, but no specimen of La Tène I.

[3] Figured in *Proc. Som. Arch. Soc.*, LVIII. i. 121.

the vertical depth from the top of the bow to the bottom of the catch-plate being only 13 mm. The bow is ornamented with three parallel grooves arranged lengthwise which terminates in two slight transverse incisions at the catch-end. The tip of the retroflected end almost touches the front of the bow, at a point where there is a decided hollow in the bow. The up-turned end has two flat, circular enlargements; all the other parts of the catch-plate and nose are ornamented with transverse ribbing. This brooch was found on the W. margin of the superimposed hearths in Mound IX., depth 3·5 ft. below the surface.

(EE 10). Fibula of the first century A.D., showing a blending of Late-Celtic with Roman art, and having a hinge-pin; length 47 mm. The tapering bow and nose make an ogee curve. As in EE 9, two transverse grooves occur at the point where, in brooches of earlier type, the retroflected end was attached to the bow. This specimen was found in Mound XII., on the top floor, 1·2 ft. below the surface. A similar fibula was found on Ham Hill (Taunton Museum) and has been figured.[4]

Last September Meare also produced an ornamented finger-ring of flat bronze (E 74); half a wire ring—not for finger (E 72); and a circular ring (E 73), external diameter 49 mm., the ends connected by means of a rivet (rivet missing, hole remaining). The greater part of this solid ring is 'lobed' the whole way round the surfaces of the material. It belongs, perhaps, to the earliest La Tène period.

Iron.—The iron objects found this season were few, and included the greater part of a sickle (I 52), pieces of rings, and a large ferrule of flat iron (I 53).

Lead and Tin.—A rough leaden ring (L 10), and a lump of galena (L 9).

Glass Beads.—Fifty beads have already been found at Meare—twice as many as were collected in the whole of the excavations at Glastonbury. Twelve were found last September, and they include a new type in black paste (G 50), ornamented with a row of large dots and circles in relief (the circles overlap one another). There are four small ring-beads of a yellow paste, a blue bead (G 39), a globular blue bead inlaid with yellow spirals (G 46), three of clear glass with yellow spirals, and two of clear glass with yellow wave-pattern. One of the latter (G 41) is drilled transversely from one side, but this hole does not meet the main hole of the bead. This new feature occurs also in the blue and yellow bead, the sides of which have two fairly deep circular depressions and traces of a third just begun.

Kimmeridge Shale.—Parts of eleven armlets (K 35 to K 45), the material varying in thickness from 6 mm. to 19·5 mm. The greater part of the plain armlets K 37 and K 43 were found. Two pieces ornamented with double oblique grooves, from Mound IX., may belong to the same bracelet. K 39 represents rather more than one-quarter of a large stout armlet (not lathe-turned), composed of shale measuring 19·5 mm. by 14 mm. Its moulded edges are ornamented, one with a zigzag pattern, the other with transverse hatching.

[4] *Proc. Som. Arch. Soc.*, LVI. ii. plate facing p. 55, fig. 7.

Weaving-combs of Antler.—The ten combs found last September bring the Meare collection up to fifty-six. The new specimens, HH 47 to HH 56, are for the most part in good condition, and three of them are perfect. Only five examples of what was then regarded as a rare type, viz., Type 2,[5] those with oval or rounded enlargements at the handle-end, were found at Glastonbury. Of the ten specimens now found at Meare, no less than seven are of this type (the longest measuring 7 inches in length; two of these are perforated through the enlargement. One is of Type 1, another of Type 4; the remaining one is broken at the handle-end. One of those of Type 2 (HH 56) has the enlargement ornamented with two large concentric circles with a central dot; both margins of the handle are engraved with a row of eight large semicircles, each of which encloses the usual dot.

Other Antler.—We have only nine specimens to record from the recent excavations, and these include two unworked tines of roe-deer (H 106 and H 107). Perhaps the most interesting object is the polished red-deer tine (H 105) into which an iron peg (projecting 5·5 mm.) has been driven 2⅝ inches from the tip of the tine, causing the tine to split for a distance of 1¾ inch. An attempt had been made to drive the peg in nearer the tip. H 111 is part of a highly polished 'cheek-piece.' A small ferrule (H 110) with smooth convex sides was also found. A neat piece of work is half an antler ring (external diameter 34 mm.) carved into a twisted rope-pattern design (H 108).

Spindle-whorls.—Meare has already produced seventy-nine spindle-whorls, of which fourteen were found last September. The most interesting is the grey stone specimen (W 78) grooved round the sides and having radiating notches at the mouth of the hole on both surfaces (similar to a whorl from Glastonbury). The others are on the whole rather rude specimens, and were formed from lias and other stone and baked clay.

Flint.—Two well-worked scrapers, and part of a small chipped and partly polished celt (F 56). Flint was also represented by a large number of flakes, a few burnt flakes and scrapers, and two nodules (one of chert).

Querns.—Sixty-four saddle and rotary querns have now been found at Meare, besides several fragments unnumbered. Fifteen of the specimens were found in September 1914, all, or nearly all of them, saddle querns. The rotary quern is comparatively rare at Meare.

Other Stone Objects.—Of the fifty-three whetstones found in Mound IX. last year, one (S 50) showed much wear from sharpening; another piece (S 49) was deeply grooved by tools in two places; and the butt-end of a shapely specimen (S 57) was perforated for suspension, and the hole countersunk very neatly on both surfaces. Some of the hammer-stones discovered were well shaped (especially S 52, 53, and 55). Two hundred and ninety-three sling-stones (S 54) were found scattered over a small area in Mound IX.; the same dwelling produced 111 sling-stones in addition. Several small discoidal stones—perhaps intended for the manufacture of spindle-whorls—were found; also a few small smooth pebbles.

Pottery.—Late-Celtic pottery has been no less plentiful than in

[5] The types are described in *Glastonbury Lake Village*, i. 270, *et seq.*

former seasons, and includes a large number of ornamented fragments. Little of it has, however, been repaired or classified yet. A small unornamented pot (P 48), almost perfect, was found in Mound IX., and from the same dwelling we obtained a large black pottery vessel (P 50)—now restored from many fragments. It is hand-made, and in its original condition it must have been far from symmetrical. It is 12¼ inches in height. At an inch and a half below the rim the pot is encircled by a cordon, and below this the ornamentation takes the form of a bold wave-pattern also in relief and covering a width of two inches. The same pattern, not in relief but grooved, occurred at Glastonbury.

P 51 from the top floor of Mound IX. is an interesting piece—a high foot-ring or hollow base of a vessel with a round hole or omphalos of a late and debased character, probably dating from near the end of the second century B.C. and similar to a few others found at Glastonbury and Wookey Hole. Its nearest parallel is probably the late type from Hengistbury Head, figured in the Report on those excavations, 1915, plate xvii. fig. 14.

Human Remains.—Fragmentary human remains from Meare number only ten; none were found in 1914.

Tusks.—Several boars' tusks were found, including two perforated specimens (T 16 and T 17).

Animal Remains.—Plentiful, including several bird-bones and an otter's skull. Knife-cut and gnawed bones were frequently met with, and in Mound IX. saw-marks were observed on eight horn-cores.

The Committee are desirous that they should be authorised to act for the ensuing year on the part of the British Association, and that a grant of 20*l.* should be made in aid of the exploration so that the work may be resumed as soon as the war is ended. The exploration is mostly paid for by local effort, and will be discontinued during the war.

The Age of Stone Circles.—Report of the Committee, consisting of Sir C. H. READ (*Chairman*), Mr. H. BALFOUR (*Secretary*), Dr. G. A. AUDEN, Professor W. RIDGEWAY, Dr. J. G. GARSON, Sir A. J. EVANS, Dr. R. MUNRO, Professors BOYD DAWKINS *and* J. L. MYRES, Mr. A. L. LEWIS, *and* Mr. H. PEAKE, *appointed to conduct Explorations with the object of ascertaining the Age of Stone Circles.* (*Drawn up by the Secretary.*)

OWING to the necessarily late date of the excavations at Avebury Stone Circle in 1914, it was not possible to present a full report of the work carried out at the meeting in Australia. An interim report was submitted, but was not printed, and it was considered advisable to postpone the presentation of a complete Report for 1914 until it could be combined with that for 1915. During the 1914 excavations at Avebury, the object of the Committee was (1) to conduct excavations in the fosse immediately to the east of the entrance-causeway leading from Kennet Avenue, and to reach the original bottom of the fosse at this

point, with a view to exploring the lowest layers of silting and exposing the original surfaces of the fosse and causeway; (2) to cut through the vallum so as to lay bare the old surface line. Mr. H. St. G. Gray was again employed to carry out the work under the general direction of the Committee. Careful survey-plans were made of this portion of the monument and of the portions excavated, and a number of photographs were taken. These were submitted together with the interim report. Mr. Gray's report upon the work which he carried out is appended, and takes the place of the abridged account presented to the Australian meeting.

The finds, although not as numerous as could have been desired, have so far borne out the impressions derived by the Committee from previous excavations both at Avebury and elsewhere (Arbor Low in Derbyshire and The Stripple Stones on Bodmin Moor, Cornwall). No trace of metal was discovered in the lowest layers of silting in the fosse, nor on the old turf line below the vallum, and the probability of the earthworks and stone circle at Avebury being referable to the Late Neolithic period is sustained by the recent evidence. At the same time, it is most desirable that the exploration of the original bottom-surface of the fosse should be prosecuted further, with a view to laying bare a larger extent of this surface and increasing the number of finds therefrom. The most reliable evidence as to the date of the monument is to be derived from the lowest layers of the silt in this gigantic ditch. In the hopes that further excavation work would be able to be undertaken, the trenches already cut were not filled up, but were left open, a fencing having been erected round this part to protect cattle and horses. The immense original depth of the fosse can thus be seen, as also the conformation of the east side of the entrance-causeway. This should prove of much interest to archæologists.

Application was made at the Australian meeting for a further grant to enable this work to be carried out during 1915, and a sum of 20*l.* was allotted. Owing, however, to the effects of the war, it was found that it would be impossible to secure the labour necessary for the work contemplated, and the Committee felt obliged to abandon the proposed plan of operations. It was recognised, moreover, that the continuance of the war rendered such work inopportune. Nevertheless, a very useful and important piece of work was carried through during the spring of this year. The very careful survey of the Avebury Circle, on a scale of 40 feet to the inch, which had been from time to time plotted out by Mr. Gray during the excavations in previous years, was completed, and has since been carefully mounted by Messrs. Stanford. This will prove to be by far the most reliable and complete plan of the monument, and the portions excavated are accurately indicated upon it, and can thenceforth be located with certainty. A small sum was drawn for this purpose from the British Association grant.

In view of the unavoidable postponement of the important excavation work on account of the dearth of labour and on account of the serious troubles in which the country has been involved, the Committee ask that the unexpended balance of the grant made in 1914 may be credited to them, and that this may be increased to 40*l.* in all, so that

the proposed work may, if national circumstances permit, be efficiently carried out in the spring of 1916. Permission is also asked for, as previously, to apply for financial support from outside sources. This is rendered necessary on account of the very extensive excavations which are necessary before the lower strata can be reached. The results so far obtained amply warrant a renewed application for funds for the further exploration of this most important archæological site. In any case, a sum of not less than 15*l.* will be required for filling in and making good the excavated areas at present remaining exposed, but it is hoped that means may be available to enable the inevitable filling in to be effected concurrently with fresh exploration.

The Committee wish to express their thanks to Major L. D. C. Jenner, the owner, and to Mr. E. A. Parsons, the tenant, for their permission to conduct excavations upon the selected portion of the monument, and to the former for the loan of materials. Thanks are also due to Dr. W. Wright, Mr. C. Reid, and Mr. E. T. Newton for their kindness in examining and diagnosing some of the finds.

The Avebury Excavations, 1914. *By* H. St. George Gray.

I. *Introductory Remarks.*

The following account of the work of excavation carried out at Avebury in 1914, under the general direction of the Committee, is a report upon two large cuttings, which, owing to their extent and the great depth of the fosse, could not be completed in the time at my disposal, although the digging was in progress from April 11 to May 5 (exclusive of the time occupied in filling-in that part of the vallum-cutting so far completed). The writer is therefore placed at considerable disadvantage in arriving at any general conclusions, especially as very little of the lower silting has yet been removed from the comparatively large area of fosse which was under examination. For these reasons, this report will comprise a description of the excavations and the finds generally, the question of date and the comparison of this with previous work being deferred until the two cuttings, or at any rate the important fosse excavation, have been completely examined.

A maximum number of sixteen men was employed, but we were generally working with from twelve to fourteen; one half of them had had previous experience at the Avebury excavations either for one or more seasons. The weather was remarkably fine except during the last day or two, but only an hour was lost owing to heavy rain.

Sectional diagrams of the fosse and vallum were made as the work proceeded, the position of the more important objects being clearly indicated. Twenty-three satisfactory photographs (half-plate) were taken during the season, and these, added to those taken between 1908 and 1913 (which number 86), not only show the progress and chief features of the excavations, but also include general views, together forming a somewhat complete photographic survey of Avebury.

The reports already published [1] on the excavations at Avebury deal chiefly with the investigations which were carried out in 1908, 1909, and 1911 [2] in the S.S.W. fosse on Lord Avebury's property.

[1] *Brit. Assoc. Reports*, 1908, pp. 400-413; 1909, pp. 271-284; and 1911, pp. 141-152.

[2] The work of 1912 was confined to making the greater part of a survey-plan of Avebury, which will be completed this year (scale 40 ft. to the inch).

In 1909, as the termination of the S.S.W. portion of the fosse was not located at Cutting III. (close up to the road-hedge), its exact position evidently occurring under the present road into Avebury from Devizes and Marlborough, small trial-cuttings (Nos. IV., V., VI., and VII.) were made on the east side of the road and in proximity to the two large standing stones of the great outer circle. This led to the discovery of the southern entrance-causeway, the line of which is now represented by the small plantation of beech-trees on Major Jenner's property and a small part of the grass-field on Lord Avebury's land between the beech-trees and the two large stones (the portals of the entrance-way into the central area).

This causeway has already been described in the 1911 Report, but it will be desirable to repeat the chief features then revealed. As far as the solid causeway could be examined (and the trees were a hindrance to investigation), its ancient surface of solid chalk was reached at an average depth of 1 7 ft. below the present surface, and found to be about 24 ft. wide.[3]

On the east side of the causeway the level of the solid chalk was found to recede gradually as if sloping off to join the upper margin of the end-wall of the S.S.E. fosse, and taking the form of rough, slight ledges not very clearly defined. On the west side such obstacles as the wooden fence, the bank and hedge, and the modern road itself prevented any exact determination of the manner in which the S.S.W. fosse finished and the causeway began.

'The vallum now remaining nearest the causeway would appear to have obstructed the entrance-way from the Kennet Avenue, but this is not really so, for allowance must be made for the silting-down of the material composing the vallum at its end, forming a talus, and for the fact that other beech-trees have been planted in this position, caused obstruction, and gathered round them a certain amount of decayed vegetable matter' (Report, 1909).

The work of 1914 was confined to a very large excavation (Cutting IX.) into the silting of the fosse on the east side and against the solid chalk causeway, and a cutting (No. X.) through the greater part of the S.S.E. vallum. The crest of the vallum in the position of the east end of Cutting IX. is about 31 5 ft. higher than the surface of the silting of the fosse, and the latter is 14 ft. below the central area (outer circle). There is a decided berme between the fosse and vallum in the position of the 1914 excavations.[4]

II. *General Observations on Cutting IX., through the S.S.E. Fosse, 1914.*

The fosse excavation marked out for examination measured 44 ft. in length, and the width was regulated by the line taken by the escarp

[3] 24 ft. is the distance which exists between the two remaining standing-stones of the great outer circle at the entrance to the central area.

[4] This berme was noticed by the Rev. A. C. Smith in *Guide to the Antiquities of the North Wiltshire Downs*, 1st edit., 1884: 'The rampart for a considerable portion of its circuit shows an apparent terrace or "berme" halfway up its side, though this is in reality only the original level of the ground upon which the excavated earth from the fosse was thrown up.'

and counterscarp of the fosse. This part of the ditch being near the road had been used as a receptacle for all manner of rubbish and pots and pans, all of which had in the first place to be cleared, together with the stumps of many bushes. Then, with the owner's permission, four young trees of some fifteen years' growth were removed from this position and transplanted. Afterwards in the removal of the silting, even at considerable depths, the work was much impeded not only by the roots of the bushes and young trees, but also by those of many of the larger trees growing on the causeway.

The first week was devoted to the removal of comparatively recent silting at the end of the fosse and along the eastern margin of the causeway down to the level of the surface of the silting at the east end of the cutting. On the completion of this work the true and enormous dimensions of the upper margin of the fosse and its termination against the side of the causeway was revealed.

From the summit of the ancient entrance (eastern margin) to the brink of the true fosse—a distance of about 18 ft.—the solid chalk was found to fall gradually, with slight ledges cut at intervals as previously mentioned. From the brink, the solid chalk profile of the fosse—in other words the eastern face of the causeway—dipped downwards at an angle of 61°, its upper margin being nearly straight (and square with the line of the fosse), with a slight concavity towards the west. Following the brink of the fosse in this part it was found that its upper margin had a maximum width of 45 ft. From the true margin of the fosse at the west end a depth of 6·5 ft. of silting had to be removed before the level of the surface of the silting at the east end of the cutting was reached.

In re-excavating the successive strata the same arrangement of concave seams of silting were met with as in the fosse cuttings described in the former reports. Almost needless to say, there was found to be a greater depth of mould and mixed silting at the west end than at the east end of the cutting, but an average section of the fosse showing the nature of the silting cannot be delineated until the remaining layers of silting have ultimately been removed.[5] It is estimated that about five-eighths of the silting in this large cutting were cleared out at the close of the season's work.

After an infinite amount of patient labour a length of 4·25 ft. of the original floor of the fosse, at the west end and against the face of the solid causeway, was uncovered at the enormous depth of 29·5 ft. below the brink of the fosse, vertically measured, that is 35 ft. below the top of the ancient causeway and approximately 54·5 ft. below the present crest of the vallum. Even with these dimensions it is difficult to realise the magnitude of this part of the re-excavated fosse without visiting the site.

The bottom of the fosse in the part already uncovered was found to be fairly level, the width on the line of the causeway being 13 ft. The lower 7 ft. of the end-wall was inclined at an angle of about 71°.

[5] In the lower chalk-rubble silting in Cutting IX. there were occasional seams of mixed silting (fine chalk with some mould) which was much compressed and difficult to break up. There were more narrow seams of mould in the chalk-rubble in this cutting than in the others previously excavated.

In the N.W. and S.W. corners of the re-excavated fosse were two shallow channels, or 'shutes,' which appeared to be artificial and cut for a special purpose in the chalk wall; or they may be due to an unsuccessful attempt to square or round the corners uniformly. The channel on the N.W. extended from top to bottom of the fosse (tailing out at the bottom). That on the S.W. stopped about 12 ft. below the brink of the fosse, and was crossed by two or three slight ledges in the lower half.

III. *Human Remains found in the Silting of the Fosse.*

At a distance of 17 ft. from the east end and in the middle of the cutting, a contracted human skeleton (No. 214), fully adult but of small size, was uncovered at a depth of 5·8 ft. below the surface of the silting. The unexpected discovery was made in mould with very little admixture of chalk, at a time, unfortunately, when the surrounding ground owing to a drizzling rain was sticky and slippery. My absence at breakfast was also unfortunate, and on my return several of the bones had been removed and the skull had evidently been trampled upon before any part of it was actually seen by the workmen engaged at this spot. Some of the bones had been thrown back; these, however, were collected, the picks were set aside, and the clearing of the interment and the surroundings was then carried out by Mrs. Gray and myself, with the assistance of one man. It was seen at once that the skeleton, although the bones were in sequence, was in a decidedly bad state of preservation, and the bones had considerably decayed in many instances. The flexed knees touched a large sarsen stone and the head was to south. The long-bones were much decayed, with the exception of the right tibia,[6] which, however, was fractured; it was carefully measured in the ground, the length being 286 mm. (11¼ in.), which, adopting Topinard and Rollet's formulæ and taking the mean, gives a stature of only 4 ft. 3·88 in. for a female. She must therefore be classed as a dwarf.[7]

The skeleton was surrounded by twenty-three sarsen stones (measuring from 6 in. to 24 in. in length), not arranged in symmetrical order, but covering a roughly oval area about 7 ft. by 4 ft. One of the stones appeared to be half a ring-stone.[8]

[6] The tibia is not platycnemic, the latitudinal index being 731.

[7] Dwarf skeleton from Dog Holes, Warton Crag, Lancs.—Four bones of this individual are sufficiently perfect for measurement, and these are a left tibia (length 305 mm.), a left fibula (length 292 mm.), a left radius (length 226 mm.), and a right humerus (length 258 mm.). In all probability the Dog Holes femora were about 365 mm. in length when perfect. Adopting Rollet and Topinard's formulæ for calculating the height, we get an average height from the four bones for the dwarf of 4 ft. 4⅜ in. The epiphyses are united, showing that growth was complete. Age about twenty-five years. There is apparently an absence of pathological conditions (*Trans. Lancs. and Cheshire Antiq. Soc.* xxx., 1913, 113-114).

[8] In the Roman stratum above, in various places but more or less over the position of the skeleton, lumps of sarsen had been met with; two pieces measured 18 in. in length each; another 27 in. by 18 in. by 7 in.; and another 21 in. by 18 in. by 7 in. Further west a large sarsen slab was found in the surface mould, length 47 in., max. width 24 in., max. thickness 11 in. (thin on all sides). The latter was probably split off one of the stones of the outer circle and shot over into the fosse.

The calvaria of the skull was repaired as far as possible and has been examined by the kindness of Professor W. Wright, F.S.A., who reports as follows: 'The cranium was evidently of oval shape and of considerable but not extreme length. The frontal bone was in two pieces owing to the persistence of the metopic suture. The other sutures of the calvaria were only beginning to be obliterated. The skull bones are remarkable for their thickness. It is interesting to note in the fragment of the occipital region the thick character ceases at the superior curved line. From a small piece of the frontal bone one gathers that the supraciliary eminence was not well marked. The mastoid processes are small. The remains also includes a portion of the right side of the body of the mandible. The lateral incisor, canine, and first and second bicuspid teeth are all considerably worn, particularly the first two and the second bicuspid. The first molar must have been lost during life as its socket is entirely closed. The skull belonged to an individual probably over thirty years of age and of the female sex.'

Three human mandibles were found near the skeleton and at a slightly greater depth, and another in the N.W. part of the cutting. Between these remains and the human skeleton (No. 214) the chin regions of the mandibles permit of comparison. Professor Wright reports that 'they suggest a close relationship between the individuals, for they bear a close resemblance to each other. The chins, moreover, are strong and firm. The shape of the cranium (No 214) in being long is in order, but it was probably not as long as the very long ones found in the chambered long-barrows.'

It will be convenient to give the details of the mandibles here:

191. Symphysial part of the mandible of a man (height at symphysis 30 mm); no teeth remaining; in a weathered condition. 'Its chief feature is the breadth and strength of the chin' (W Wright).

Found in the lower part of the mixed silting (loamy chalk silt) and above the chalk-rubble in the N.W. part of the cutting

212. The left half and the region of the angle of the right half of the mandible of a man; somewhat weathered, like the other fragments of lower jaws, Nos. 191, 217, and 222, as if they had been exposed upon the surface at some time 'There is nothing noteworthy about this mandible unless it be that the age of the individual was probably from thirty-five to forty-five years of age' (W. Wright).

Found in the mixed silting near the human skeleton (No 214), at a depth of 6·2 ft. below the surface of the silting.

(Part of a lower jaw, No 30, was found at a depth of 8·3 ft in the chalk-rubble in Cutting I., Fosse, 1908.)

217 Part of a small mandible consisting of the chin and part of the right side, with the sockets of the bicuspid teeth remaining; weathered. 'It probably belonged to a female, and the chin, making allowances for the sexual differences, has the same conformations as that of specimens Nos 191 and 214' (W. Wright).

Found near No. 212, in the mixed silting, at a depth of 6·8 ft. below the surface of the silting

222. Part of the right side of the body of a mandible, the ascending ramus missing; of the teeth only the first and third molars remain. 'The last molar is only slightly, if at all, worn, and therefore probably the specimen came from an individual whose age was something in the early twenties' (W Wright).

Found in the mixed silting near the skeleton (No. 214), at a depth of 6·3 ft. below the surface of the silting.

Associated with the human skeleton, the following antiquities were found (all bearing the same No. 214, except the saw, No. 211, and two fragments of pottery, No. 210):

(*a*) Ball of solid chalk, rudely shaped and having an average diameter of 36·5 mm. ($1\frac{7}{16}$ in.).[9]

(*b*) Large flint core; all the surfaces are white.

(*c*) Several flint flakes, one of which is burnt.

(*d*) Metacarpus of sheep.

(*e*) Nineteen fragments of prehistoric pottery, hand-made and of soft paste. There is no trace of ornament. Some of the pieces are black all through; some black inside and reddish-brown outside. They represent fragments of more than one pot and vary in thickness from 6 mm. to 14 mm. Most of the pieces contain a small admixture of quartz grains, but for the most part they are very small.

210. Two fragments of prehistoric pottery, hand-made and badly baked, of a very soft paste and containing occasional grains of quartz and other substances. This pottery is reddish-brown on the outer face and black inside. One of the specimens is a straight rim piece somewhat bevelled on the outer side.

Found at a depth of 5·7 ft. below the surface of the silting, 4 ft. N.W. of the pelvis of the human skeleton.

211. Saw formed from a white flint, length 64 mm., having a dorsal ridge (giving a triangular cross-section). The longest edge, which is concave, is worked with fine serrations throughout its length.

Found in the mixed silting under the skeleton (No. 214), and at a depth of 6·5 ft. below the surface of the silting.

IV. *Deposits of Burnt Material from the Fosse.*

At a distance of 0·5 ft. below the skeleton a patch of dark material was reached, consisting for the most part of burnt mould. This was found to extend to a depth of 7·5 ft. below the surface of the silting. The deposit was more or less in the shape of a mound of about 3 ft. in diameter, and it was evident that a fire had been kindled on the spot. The dark area was divided by a seam of 0·2 ft. of mixed mould and fine chalk at about 0·75 ft. from the top of the dark patch. Below the dark material yellowish-brown mould occurred, followed at a greater depth by chalk rubble.

In this dark material the following objects were found (marked No. 247):

(*a*) Part of a large flint hammer-stone.

(*b*) A large quantity of burnt animal bone, mostly split up into small pieces. (Samples preserved.)

(*c*) A human incisor tooth.

(*d*) Astragalus of small ox.

(*e*) Points of four tines of red-deer, much weathered.

(*f*) Metatarsus of red-deer (not sufficiently complete for measurement).

(*g*) A number of flint flakes, of which about one-half are burnt.

(*h*) Some charcoal (identified by Mr Clement Reid, F.R.S., as beech). It might be noted here that beech charcoal was also found in this cutting in the mixed silting against the south wall of the fosse, and also in the chalk-rubble at a depth of 12 ft. below the surface.

V. *Other Finds from the Fosse, Cutting IX. (excluding Picks).*

From the Roman and later strata.—(The Roman stratum was reached at a maximum depth of 4·5 ft.)

[9] A similar ball, not quite spherical, about 2 in. in diameter, was found at the Grime's Graves in 1914 (see *Grime's Graves Report*, 1915, p. 210).

180. Ring of bronze, of bright-green colour due to patination. It consists of wire of circular section, 2 mm. in diameter; it is split transversely in one place, where the ends appear to have been notched. In external diameter the ring varies from 19·5 mm. to 20·5 mm. Probably Romano-British.

Found on the S. margin of the cutting on the top of the solid chalk wall a little below the surface mould.

192. Fragment of coarse black pottery containing a large number of small grains of quartz; apparently Romano-British.

Found in the Roman stratum on the south side of the cutting.

193. Three fragments of Romano-British pottery of no special interest.

Found as No. 192.

197. Whetstone consisting of an oblong piece of reddish-brown sandstone, measuring 87 by 76 by 21 mm., very smooth on one surface and artificially grooved obliquely.

Found in the Roman stratum, depth 3·7 ft. below the surface.

201. Rim piece of a Norman or mediæval pot, ornamented on the inner surface by a wave pattern common in the period.

Found at the east end of the cutting, depth 1·5 ft.

205. Greater part of a bronze bracelet of bright-green colour, consisting of two strands of wire twisted, and tapering in size towards the ends. Of a common Roman type, which appears to have had a hook-and-eye fastening.

Found in the middle of the cutting in the Roman stratum, at a depth of 4·25 ft. below the surface of the silting.

From the Mixed Silting.

177. Chipped flint knife, length 39·5 mm., maximum width 17·5 mm., of Neolithic type; leaf-shaped outline; slightly concave and unworked on one face; convex on the other face and finely chipped along both edges, the flaking covering most of this surface; white over the whole surface.

Found in the fine mixed silting close against the S.W. face of the fosse near the causeway, about 5 ft. below the brink.

183. Point of a tine of red-deer showing transverse cuts at the larger end.

Found in the mixed silting close to the chalk 'wall' in the N.W. corner of the cutting

187. Flake of dark bluish-grey flint, of irregular form, but having a considerable amount of secondary chipping.

Found on the side of the fosse at the N.W., near the top of the mixed silting.

213. Three points of tines of red-deer, somewhat weathered; two of them have indications of cutting near the tips.

Found in the middle of the cutting in the mixed silting (which consisted mostly of earth in this part), depth 7 ft. below the surface of the silting.

231. Two fragments of prehistoric pottery, hand-made and of coarse type. The larger fragment (12·5 mm. in thickness) is brick-red on the outside and black inside, and contains some very large rounded quartz-grains and splinters of flint, up to 6 mm. in length. 'The chalk flint looks as if it had been intentionally crushed and added to the paste for stiffening. The quartz-grains probably came from Tertiary deposits. Samples of clay as coarse as this can often be found over the chalk downs. It may have been baked by piling brushwood over the inverted pot. I see no sign of chalk or charcoal having been used in this paste' (Clement Reid).

The smaller piece is black except for the outer crust, which is yellowish-brown. 'It contains no crushed flint, and is apparently very slightly baked' (C. Reid).

Found in the middle of the cutting at the bottom of the burnt material previously described, and above the chalk rubble; depth 7·7 ft. below the surface of the silting.

No pottery was found in the fosse in 1914 at a greater depth than these fragments.

252. Rim piece of prehistoric pottery, hand-made and of coarse type (nearly as rude as the larger piece in No. 231). 'Soft paste stiffened with fragments of old pots and some grit. I cannot suggest origin without material to crush.

Well burnt outside to rim; black and slacker baked inside, suggesting that the pot was inverted and fire could only reach outside' (C. Reid).

Found quite at the bottom of the burnt material, at a depth of 7·5 ft. below the surface of the silting.

From the Chalk Rubble.—(Bone Objects).

223. Implement formed from a rib-bone of ox (or horse?), measuring 335 mm. (13¼ in) in length on the outer curve. It is cut to a rounded and somewhat bevelled termination at one end, and the surfaces are rather smoother in this part than elsewhere. At the butt-end it is also slightly polished.

Found against the solid chalk wall at the west end of the fosse near the bottom, and at a depth of 24·5 ft. below the brink.

225. Implement formed from part of a rib-bone of ox or horse; what remains measures 221 mm. (8⅝ in) in length, but it is obviously broken at the butt-end. It is cut to a rounded termination at the complete end, but more pointed than in the case of No. 223, which it closely resembles.

Found in a similar position to No. 223, at a depth of 25 ft. below the brink.

Two similarly-worked rib-bones were found in Cutting VIII , in 1911, on the bottom of the fosse. (Report, 1911, Nos. 171 and 176)

240. Small, slender, animal bone, broken off at both ends, but quite smooth; probably the shaft of a pin.

Found on the bottom of the fosse at the west end of the cutting.

VI. *Picks and other Remains of Red-Deer Antler, found in the Fosse (Cutting IX.).*

As in former seasons, picks of red-deer antler were found in some numbers in the chalk-rubble, and especially near and on the floor of the fosse. Picks of this type have also been found in Britain in considerable numbers at the Grime's Graves,[10] Cissbury, and Maumbury Rings, and in smaller quantities at many other places, generally with prehistoric remains, but occasionally on Roman sites.[11] Portions of antler picks—one piece being smoothed and charred at the handle-end—have recently been found in the great artificial mound at Marlborough College. Two very large antler picks found in the excavations at Avebury in 1894 [12] were disposed of in April 1915 at the Meux sale at Dauntsey House, near Swindon, and were acquired by the Wiltshire Archæological Society for Devizes Museum.

Twenty numbered specimens were found in the fosse in 1914, as follows:

188. Parts apparently of two antlers (or if parts of the same antler they do not join). One consists of the greater part of the beam, part of the remaining tine reduced to a stump. The other part consists of the crown of an antler of three points, the lower one of which is considerably bevelled and worn at the tip.

Found in the mixed silting in the N.W. part of the cutting, and 7·3 ft. deep below the brink of the fosse E. of the causeway.

189. Pick, well worn, consisting of the beam and burr of a shed antler, having only a very slightly developed indication of a bez-tine. The trez-tine has been reduced to a stump (more projecting than in the majority of the

[10] 244 antler picks were found in the excavations at the Grime's Graves in 1914. 147 of the specimens had also been used as hammers.

[11] Records of such finds have been brought together by Mr. Horace Sanders in *Archæologia*, lxii. 101, and by Mr. W. G. Clarke in the *Report on the Excavations at Grime's Graves*, 1914 (published 1915), p. 142, in which, however, no mention of the Avebury specimens is to be found.

[12] *Brit. Assoc. Report*, 1908, p. 404.

picks). The brow-tine has become much worn and broken. The implement has been smoothed at the handle-end. The most pronounced indication of wear is seen at the back of the beam caused by hammering, which has reduced the thickness of the antler considerably in this position, and removed the burr. Total length 470 mm. (18½ in.).

Found in the mixed silting close to the causeway in the N.W. part of the cutting, depth 8·3 ft. below the brink of the fosse.

196. Part of a pick formed from a shed antler. The bez-tine remains as a fairly long stump; the brow-tine is broken but still bears traces of human work. The back of the head of the pick and the burr bear clear evidence of hammering. Length 344 mm. (13½ in.).

Found in the mixed silting and rubble in the W. part of the cutting, depth 9·8 ft. below the brink of the fosse on the E. side of the causeway.

208. Pick damaged at the handle-end, having the bez- and trez-tines reduced to stumps, and the brow-tine broken off. This pick was formed from a large antler of a slain deer. Its most interesting feature is the large cavity at the back of the beam and head, the result of considerable wear from hammering. Length 394 mm. (15½ in.).

Found near the W. end of the cutting in the chalk-rubble, depth 12·8 ft. below the brink of the fosse on the E. side of the causeway.

209. Base of a large antler of a slain deer, with pedicle 3 in. in length. The burr is much worn down and the bez-tine is indicated merely by a stump. A good part of the brow-tine remains, but it has been broken.

Found in the N. half of the cutting in the chalk-rubble, depth 17 ft. below the brink of the fosse on the E. side of the causeway.

215. Shed antler, with the brow-, bez-, and trez-tines complete; the crown of the antler is missing. It bears no signs of human work.

Found in the middle of the cutting in the lower part of the mixed silting (yellowish-brown mould and chalk), depth 8·7 ft. below the surface of the silting.

216. Part of a pick consisting of the beam of an antler, the trez-tine reduced to a stump. The burr, brow-, and bez-tines broken off. At the back of the beam there are traces of a depression, the result of hammering.

Found in the chalk-rubble in the N.W. quarter of the cutting close to the end-wall of the fosse, at a depth of 22 ft. below the brink.

218. Crown of an antler, one of the three points missing, the other two somewhat worn down and broken at the tips. It has the appearance of having been used as a rake.

Found in the chalk-rubble in the N. half of the cutting, depth 18 ft. below the brink of the fosse on the E. side of the causeway.

219. Pick, almost complete, formed from a small shed antler having two tines, the upper one reduced to a stump and bearing slight traces of fire. The brow-tine has been considerably worn down by picking. The back of the burr has been broken off. Length 489 mm. (19¼ in.).

Found in the chalk-rubble in the S. half of the cutting, depth 24·5 ft. below the brink of the W. end of the fosse.

224. Part of a pick consisting of the beam with the trez-tine remaining as a stump. The back of the beam is much worn by hammering.

Found in the chalk-rubble in the S. half of the cutting, depth 25 ft. below the brink at the W. end of the fosse.

226. Pick, much damaged, consisting of a shed antler with brow-tine broken off; the bez- and trez-tines reduced to stumps, the latter bearing indications of fire. The back of the beam and head of the pick bear distinct evidence of its use also as a hammer.

Found in the chalk-rubble at the W. end of the cutting, 25 ft. below the brink.

227. Pick, almost complete (shed antler), the brow-tine reduced in length by wear and fracture; the bez- and trez-tines reduced to stumps; the latter and the handle-end are blackened in parts by the action of fire. There is evidence at the back of the head that the implement was also used as a hammer. Length 500 mm. (19⅝ in.); circumference of the beam 159 mm.

Found in the N. half of the cutting on the bottom of the fosse, against the end-wall and 29·5 ft. below the brink.

228. Pick, almost complete (shed antler), the brow-tine bearing indications of considerable wear; the bez- and trez-tines reduced to stumps. There is clear evidence of this implement having also been used as a hammer, like No. 227. Length 474 mm. (18⅝ in.).

Found in the N.W. corner of the cutting on the bottom of the fosse, against the end-wall and 29·5 ft. below the brink.

229. Greater part of a much-worn pick formed from a shed antler. The brow-tine is much shortened by wear and fracture; the bez- and trez-tines reduced to stumps. This implement was largely used as a hammer and there is a deep cavity at the back of the beam penetrating one-half of its diameter; the burr has also been broken away by hard wear. Length 350 mm. (13¾ in.).

Found at the W. end of the cutting against the end-wall, on the bottom of the fosse, depth 29·3 ft. below the brink.

230. Pick formed from a large antler of a slain deer with pedicle, the burr much worn down at the back. The large brow-tine has been reduced in length by wear and the 'tip' is now quite blunt; the bez- and trez-tines have been shortened in the usual manner. Indications of fire are noticeable near the burr, at the base of the bez-tine, and at the handle-end. Length 521 mm. (20½ in.); minimum circumference of the beam 165 mm.

Found at the W. end of the cutting against the end-wall, on the bottom of the fosse, 29 ft. below the brink.

234. Part of a pick formed from a shed antler, the handle-end missing. The greater part of the brow-tine remains and bears indications of wear; the bez- and trez-tines reduced to stumps. The condition of the back of the beam and burr indicates that the pick, as in most other instances, was also used as a hammer.

Found in the chalk-rubble in the N. half of the cutting, depth 20·5 ft. below the brink

235. Pick, much damaged and in a very fragile condition, not preserved.

Found close to No. 234, and at the same depth.

236. The greater part of the beam of an antler, bearing traces of fire, and perhaps part of a pick.

Found at the W. end of the cutting, depth 25·5 ft. below the brink.

237. Pick formed from a large shed antler having the burr partly removed. The brow-tine is nearly complete, the tip in places being smooth from wear; the bez- and trez- tines reduced to stumps. Length 467 mm. (18⅜ in.); circumference of the beam between bez- and trez-tines 170 mm. (6¾ in.).

Found in the chalk-rubble in the S. half of the cutting, 16·5 ft. below the brink.

239. Shed antler, not worked, with short undeveloped bez tine and only two points at the crown. Total length 672 mm. (26⅜ in.).

Found on the bottom of the fosse at the W. end of the cutting, average depth 29 ft. below the brink.

In addition to the above four much broken and decayed antler picks (or parts) were found in the chalk-rubble, at an average depth of 12 ft. below the surface of the silting; and a piece of the beam of an antler was found on the bottom of the fosse against the N. wall.

VII. *General Observations on Cutting X., across the Vallum, 1914.*

This cutting, measuring 15 ft. in width, was made on the S.S.E. and within easy distance of the fosse-digging—so that the two excavations could be watched simultaneously. At this point the vertical height from the surface of the silting of the fosse to the crest of the vallum was 32·65 ft., and from the middle of the berme to the top, 14·4 ft. About one-half of the berme was included in the excavation which extended southwards as far as the summit of the vallum, the length examined being 50 ft. The outer part of the vallum, comprising a length of 30 ft., remains to be excavated.

The whole of the body of the rampart was found to consist of chalk-

rubble with very little admixture of mould (in the form of seams). The old turf, or surface, line (*humus*), and the dark brown material immediately below it were found to be very clearly defined, and measured on an average 3·5 in. in thickness throughout the cutting. It ran almost level, and was reached at a depth of 14 ft. below the crest of the vallum.

Upon this ancient material Mr. Clement Reid, F.R.S., who has examined a dried lump, has kindly reported as follows: 'Brown silty clay, with small splinters of flint and minute fragments of charcoal. The matrix is mainly an insoluble residue from the chalk, with the usual dark stain of mixed oxides of iron and manganese. It contains also some very fine quartz-sand, probably derived from Tertiary deposits. It is scarcely a soil, though it shows small roots; it is a subsoil into which some charcoal has been kneaded. It corresponds with the "clay-with-flints."'

Samples of charcoal found in considerable quantity on the old surface line were also sent to Mr Reid to be examined, and, like the pieces from the fosse, proved to be beech.

VIII. *Relics found in the Vallum (Cutting X.).*

We were fortunate in selecting a favourable position, for a number of relics were discovered on the ancient surface and elsewhere. Several of the fragments of pottery, mostly very small, were recovered from the old surface by breaking the mould up in the hands and sifting. Flint flakes were very plentiful; metals were conspicuous by their absence. One of the most interesting specimens is the finely-worked bone pin, No. 186. A fourpenny-bit of William IV., 1836 (No. 178), was found near the foot of the interior slope of the vallum in the turf mould, depth 0·4 ft.

The following is a detailed catalogue of the objects found in the vallum cutting. All the depths are given vertically—below the turf immediately above. O.T.L. = Old turf line.

Flint Implements.

190. Thin, sharp flake; white.
Found in the chalk-rubble, depth 6·5 ft.

198. Scraper of comparatively rough workmanship; grey flint with a white outer crust on the greater part of the convex surface.
Found on the O.T.L., near the foot of the interior slope.

199. Scraper of an elongated horse-shoe shape, length 37 mm., the crescentic edge finely worked; colour white, and pale grey in places.
Found on the O.T.L., near No. 198.

200. Saw of light-grey flint, with finely-worked serrated edge almost straight (length 47·5 mm.).
Found on the O.T.L., near Nos. 198 and 199.

204. Saw of light-grey colour, calcined; the serrated edge (length 28·5 mm.) is not so finely worked as in the specimens, No. 200 (vallum) and No. 211 (fosse).
Found on the O.T.L., a little to the south of No. 200.

206. Scraper of greyish-white flint of a long narrow form, length 41 mm. The flake from which the implement was formed has a dorsal ridge giving a triangular cross-section. The crescentic edge (width 24 mm.) is bevelled and neatly chipped.
Found on the O.T.L., near No. 200.

207. Part of a neatly-chipped implement of white flint of which the base is missing. The business-end is considerably bevelled and worked on the convex side. Flaked on both surfaces.

Found on the O.T.L., near No. 206.

221. Scraper (?) of white flint, thin, and of an irregular oval outline, 43 mm. by 46 mm.; it is bevelled and chipped on all sides but the base.

Found on the O.T.L., at the N. end of the cutting under the berme (dividing the vallum from the fosse).

241. Long, narrow flake (length 61 mm.), of light-grey flint, the crust of which extends along one side of the back. At the junction of the flat side of the flake with the crust the specimen is slightly jagged, but this saw-like edge does not appear to be the result of secondary chipping.

Found on the O.T.L., 4 ft. N. of the crest of the vallum, depth 13 7 ft.

242. Scraper of pale-grey colour; horse-shoe form, with a prominent bulb of percussion; length 42 5 mm.; the crescentic edge is roughly bevelled and worked.

Found on the O.T.L., a little south of the foot of the interior slope.

245. Saw of white flint formed from a long flake with a dorsal ridge; the serrated edge (length 55·5 mm.) is somewhat irregular, and not so well worked as Nos. 200 and 211.

Found on the O.T.L., under the body of the vallum and in the middle of the cutting.

255. Pointed flake of greyish-white colour with saw-like secondary chipping along one edge.

Found on the O.T.L.

Flint Flakes.

There were also collected from the old turf line sixty-four flakes of light grey-and-white flint, four of which are calcined.

Antlers, including a Pick.

181. Crown of a small antler consisting of two points; red-brown colour.

Found in the chalk-rubble in the body of the vallum, depth 3 ft. below the surface.

184. Greater part of a small shed antler, red-brown colour. There is no positive evidence that this specimen was a pick, as the brow-tine is broken and the other tine some way up the beam has not been shortened; but the end of the beam nearest the crown has been burnt in a similar manner to some of the handle-ends of more definite picks.

Found in the chalk-rubble in the body of the vallum, depth 4 ft. below the surface.

232. Part of a small pick formed from a shed antler having a rudimentary bez-tine; the brow-tine was badly fractured at the time of its discovery, but the point is worked and very smooth.

Found in a slight 'mound' of mould (probably decayed turf), 0·2 ft. above the old surface under the crest of the vallum.

253. Complete tine of red-deer antler, smooth at the point.

Found in the chalk-rubble in the body of the vallum.

Bone Objects.

182. Small, flat piece of bone (length 33·7 mm.), rounded at the complete end, and of similar workmanship to the larger worked rib-bones, Nos. 223 and 225, found at the bottom of the fosse.

Found in the body of the vallum, depth 6 ft.

186. Finely-worked pin, slightly curved, with faintly tooled and polished surface; length 86 mm. (3⅜ in.), the shaft of oblong section, maximum dimensions 2·5 mm. by 4 5 mm. One end is finely worked to a sharp point of round section; the other end is cut off slightly oblique to the line of the pin, and is bevelled on both the flat faces of the implement.

Found in chalk-rubble in the body of the vallum, 3 ft. N. of the crest, depth 5·5 ft.

The writer has not yet come across a similar pin found with prehistoric remains in Britain.

Pottery.

194. Two fragments of fairly well-baked black pottery, containing a good proportion of small grains of quartz-sand and some larger pieces measuring up to 4·5 mm. in length.

Found on the O.T.L., near the foot of the interior slope.

195. Fragment of badly baked pottery, black on the inside and reddish-brown on the outside; it contains a small admixture of small quartz-grains.

Found close to No. 194.

202. Fragment of black pottery similar to No. 194, and perhaps part of the same vessel.

Found on the O.T.L., near Nos. 194 and 195.

203. Eight small bits of pottery, and a fragment of iron pyrites. The pieces belong to more than one vessel; three of the fragments appear to be parts of one pot only, 5·5 mm. thick. This ware is of a very coarse kind, some of the pieces containing grains of quartz up to 6 mm. in length.

Found on the O.T.L., near Nos. 194, 195, and 202.

220. Twenty-two fragments of pottery of various degrees of coarseness—all undoubtedly prehistoric (perhaps Neolithic), and belonging to vessels varying in thickness from 4·5 mm. to 10·5 mm. They range in colour from a light reddish-brown to black. Some of this ware consists of very soft paste with only a small admixture of quartz-grains, but most of it is roughly made with large grains projecting from the weathered surfaces of the ware; the largest grain of quartz observable measures 4 mm. by 6 mm.

They include one small piece of rim and two ornamented fragments belonging apparently to the same pot, which had an encircling shoulder or ridge with a hollow moulding probably below the shoulder, and similar in these features to the pottery, No. 167, found in Cutting VIII., Fosse, 1911; the type is described at some length in the writer's 1911 Report.[13] As far as can be traced, the two fragments are ornamented with oblique and parallel bands of punch-marks consisting of lozenge-shaped clusters of four impressed oval dots.

Mr. C. Reid, who has seen one of the coarsest unornamented fragments, writes: 'Thin well-burnt pottery, not local; the grit is all vein-quartz, and suggests Bristol Coal-field.'

Found on the O.T.L., at the N. end of the cutting under the berme (dividing the vallum from the fosse).

243. Six fragments of pottery, two being of thin reddish-brown ware and of comparatively fine texture. The other pieces, which are thick—black on one side and brown on the other—are very rude and of the coarsest possible description, and contain an admixture of large quartz-grains; in one fragment there are two pieces of quartz, measuring 4·3 mm. by 7·3 mm. and 4·2 mm. by 4·2 mm., which actually touch each other.

The last described fragment has been seen by Mr. Clement Reid, who writes: 'Not local; paste black, and sandy, and full of splinters of grit, with some large quartz-grains. The splinters look like Carboniferous Limestone chert, rather than chalk-flint, but there is not enough material to make certain. Perhaps from the Mendips.'

Found in a similar position to No. 220, but a little nearer the interior slope of the vallum.

244. Two fragments of pottery, one of which is black on the inside and brick-red on the outside, of fairly hard paste and containing quartz-grains of no great size. The other fragment is of dark grey colour, fairly hard, and containing small quartz-grains with a small admixture of larger grains.

Found on the O.T.L., under the body of the vallum, 10·5 ft. N. of the crest, depth 11·8 ft.

251. A few small fragments of badly baked pottery similar to No. 195, but apparently containing very little quartz-sand.

Found on the O.T.L.

IX. *Animal Remains.*

Only the more interesting specimens were preserved. Those found

[13] *Brit. Assoc. Report*, 1911, pp. 147, 150.

near the surface and others in a very fragmentary condition were reburied. Some of the specimens have been kindly examined by Mr. E. T. Newton, F.R.S.

Cutting IX., Fosse.

238. One side of lower jaw of dog, and a number of teeth belonging to the other side also. The animal was about the size of a retriever.

Found on the bottom of the fosse in the N. half of the cutting, and near the end-wall against the causeway.

Near No. 238, also on the bottom of the fosse, several teeth of dog of similar size were found.

246. Occipital portion of skull of red-deer; height from the bastion to supraoccipital crest 89 mm.

Found in the chalk-rubble, depth 11 ft. below the surface of the silting.

248. Metacarpus of red-deer, length 274 mm.; least circumference 78 mm.

Found in the Roman stratum.

249. Part of metacarpus of red-deer.

Found at a depth of 6·5 ft. below the surface of the silting.

250. Metatarsus of red-deer, length 315 mm. (12¼ in.); least circumference 81 mm.

Found at a depth of 8 ft. below the surface of the silting.

A red-deer at the Royal College of Surgeons, having a metatarsus 10⅜ in in length, stands 44½ in at the withers. The Avebury stag, therefore, stood about 50 in. at the withers

254 Lower end of femur of large ox

Found on the bottom of the fosse.

Cutting X., Vallum.

179 Part of radius and other remains of ox (rather small).

Found in chalk-rubble in the body of the vallum, depth 4 ft.

185. Greater part of tibia of young ox; the shaft is split obliquely—perhaps for the extraction of marrow.

Found in chalk-rubble in the body of the vallum, depth 4·25 ft.

232. Shaft of tibia of ox, the heads broken off at both ends as if for the extraction of marrow.

Found close to the O.T.L., with the small antler-pick also marked No. 232.

233. One end of femur of young ox.

Found on the O T.L, near No. 232.

Four teeth of pig were also found on the O.T L

Physical Characters of the Ancient Egyptians.—Report of the Committee, consisting of Professor G. Elliot Smith (*Chairman*), Dr. F. C. Shrubsall (*Secretary*), Professor A. Keith, Dr. F. Wood Jones, *and* Professor C. G. Seligman.

Professor Elliot Smith's Report.

In last year's Report of the Committee I referred to the fact that material of great historical importance[1] was being found by Professor Reisner at Kerma, near the Third Cataract, and that some of the skeletons had been sent to me in Manchester for examination. Since then a very large collection of human remains from the same site has

[1] Report of British Association, p. 228, B., 'The Human Remains from the Kerma Basin,' &c,

been received from Dr. Reisner; and, although most of this material has now been photographed and measured, the investigation of it is not yet sufficiently advanced to permit me to submit a final Report upon it. It is of sufficient importance, however, to justify an interim Report.

In the Bulletin of the Boston Museum of Fine Arts, April 1914, Professor Reisner has published a very interesting and fully-illustrated account of his excavations at Kerma, with a description of the circumstances under which the human remains were found and the nature of the remarkable series of objects found with them.

In this report the human remains are described as those of 'a garrison which held the Northern Sudan in the Hyksos Period, about 1700 B.C.' To appreciate more fully the nature of the material with which I have to deal I may be permitted to quote Dr. Reisner's own account of the problem he puts to me to solve for him.

'By 2600 B.C. the Egyptian had already begun his exploitation of the Upper Nile, and had been led in military force as far as the province of Dongola, the richest area between the Assuan border of Egypt and the tropical Sudan. Gold he certainly brought away and cattle; ivory, ostrich feathers and eggs, ebony, skins, resins, spices and incense—all came through the province in trade if they were not produced here.' Traces of the Old Empire fort and alabaster vessels bearing the name of Pepy I. were found at Kerma. 'During the period of depression in Egypt which followed the reign of Pepy II., it is probable that the Nubian tribe went their own way undisturbed. In the Middle Empire, however, the exploitation of Nubia by Egypt was resumed and placed on a more secure footing. Sesostris III. set up a boundary-stone at Kummeh, south of Halfa [Second Cataract], forbidding any negro to pass northwards by land or water except traders and official messengers. This stone marked the southern border of Egypt, but, as a matter of course, not the limits of Egyptian activity.' [Inscriptions with the names of Sesostris I., Amenemhat I. and Amenemhat III., together with fragments of perhaps twenty-five Middle Empire royal statuettes, make it] 'quite clear that Kerma was held by the kings of Egypt during the Middle Empire.

'Thus we come to the Hyksos Period itself. Much has been written about this period in Egypt, but our real knowledge is small. An unidentified race came in, apparently from Asia, conquered and held Egypt for perhaps a hundred years. But we do not know how far south they held it . . . [at Kerma] in the Hyksos period [there have come to light the remains of] a colony of men, not negro, and yet not using Egyptian furniture nor Egyptian burial customs. They razed the buildings of the Egyptians of the Middle Empire; they smashed the statues of Egyptian kings of the XII. Dynasty; and they made their graves in the débris of an ancient mud-brick structure. They were apparently a fierce and capable race. Their pottery, manifestly made locally, is the finest and most beautiful ever made in the Nile Valley. . . . Their burial customs are revolting in their barbarity. On a carved bed in the middle of a big circular pit the chief personage lies on his right side with his head east. Under his head is a wooden pillow; between his legs a sword or dagger; beside

his feet cowhide sandals and an ostrich feather fan. At his feet is buried a ram, with ivory knobs on the tips of its horns to prevent goring. Around the bed lie a varying number of bodies, male and female, all contracted on the right side, head east. Among them are the pots and pans, the cosmetic jars, the stools, and other objects. Over the whole is spread a great ox-hide. It is clear they were all buried at once. The men and women round about must have been sacrificed so that their spirits might accompany the chief to the other world. . . . I could not escape the belief that they had been buried alive. Who are these people? There are, it is true, a few negroes among the women; but the chief men are all broad-headed and straight-haired. If they are Egyptian, whence comes the strange pottery and the awful burial custom? It is hoped to submit the bones to Prof. Elliot Smith, who will without doubt be able to say whether the men were Egyptians or not. If they are neither Egyptians nor negroes, then there are many possibilities—Arabs, Libyans, a mixed band of adventurers from the north, or even Hyksos. The name of Sheshy, supposed to be a Hyksos king, is found on several of the seal-impressions. But it is not possible at present to reach any safe conclusion on the race of the men of Kerma.'

These free quotations from Professor Reisner's report admirably and most lucidly explain the nature of the problems I am asked to solve. There is one possibility, not mentioned by Dr. Reisner, that at once suggests itself, especially when one examines the excellent photographs that illustrate the report. Seeing that this very spot had been occupied by an Egyptian town and fortress nine centuries earlier, and then again later on for several centuries before the time of the people whose identity is under consideration, obviously the first explanation which suggests itself is that we may have to deal with the descendants of the old colony of Pepy's time reinforced with fresh Egyptian blood by new immigrations ranging from the time of Sesostris I. to Amenemhat III. at least.

For the statement that these people were 'not using Egyptian furniture nor Egyptian burial customs' is apt to be misleading. The furniture and the burial customs, it is true, are not *exactly* identical with those of Egypt at any period: but no one who studies the burial customs and funerary equipment of other peoples can hesitate for one moment in deciding that these things and the Egyptian customs and furniture must be assimilated into the same generic group. My meaning will be made clear if we examine the archæological evidence. Burial upon a bed of the type found in these graves was not an Egyptian custom in 1700 B.C.; but it was so at the time when the first Egyptian settlement occurred at Kerma, perhaps a millennium previously; and the legs of the chairs and beds are characteristically Egyptian in design (see Reisner's fig. 20); so are the head-rests and the sandals, and the Egyptian military decoration ('order of the fly'). The exquisite black-topped, red-polished pottery is equally characteristically a proto-Egyptian ware, but carried to a much higher pitch of perfection by eighteen centuries of practice after the Egyptians themselves had been using their most expert craftsmen for other purposes. The barbarous addition to the burial customs of the Egyptians is the well-

known negro practice of slaughtering the wives and retainers of the deceased.[2]

In the light of such considerations the hypothesis that should first be tested is that an Egyptian colony, settled in Kerma in proto-Dynastic times, continued to cultivate its original Egyptian cultural heritage, which was modified on the one hand by the taint of negro barbarism and the influence of a succession of later Egyptian immigrants.

I have put forward this tentative explanation of the archæological evidence advisedly, not merely because it naturally suggests itself as the most probable interpretation of the state of affairs found by Dr. Reisner, but also because the anthropological data, so far as I have investigated them, seem to favour this view.

Amongst the human remains there is a considerable number of individuals conforming in every respect to the proto-Egyptian type, such as is found in pre- and proto-Dynastic cemeteries in Upper Egypt. These might well represent the descendants of the original Egyptian colony which was planted in Kerma during the Old Empire. There are also many representatives of that modification of the proto-Egyptian racial type for which I coined the distinctive expression 'Middle Nubian' (the people whose culture Dr. Reisner classified as his 'C-group'). These were the people who constituted the normal population of Lower Nubia during the time from the Middle Empire until the country was overrun by Egypt in the New Empire: in other words, they were the distinctive inhabitants of Nubia during the time of the Kerma burials; and it would have been very surprising if they had not been well represented. Even in Lower Nubia they exhibited definite traces of some negro admixture; and in this respect the Kerma material agrees with the more northern remains of the same age. But in the Kerma material there is perhaps a greater variety of slightly negroid types than in Lower Nubia—a state of affairs that is not surprising considering that it is nearer the negro domain. In fact it is remarkable that strongly marked negro traits are so infrequent as they are shown to be in material from such a southerly site.

The most interesting remains that this cemetery has yielded are a minority conforming in every essential respect to the type from Lower Egypt which I illustrated in last year's Report (p. 219, figs. 1, 2, and 3). It represents a type of mankind which made itself apparent in Lower Egypt in proto-Dynastic times and spread up the river very gradually, until by the time of the Middle Empire the aristocratic population throughout Egypt was more or less permeated by the influence of admixture with such people. It is in the highest degree unlikely that the effects of such admixture could have become apparent at the Third Cataract before the Middle Empire. That it did so soon afterwards suggests—as, indeed, might have been expected—that the expeditions to the Sudan at that time were commanded by people of this aristocratic type. This is further confirmed by the results of

[2] See my article 'On the Geographical Distribution of the Practice of Mummification, &c.,' *Memoirs of the Manchester Literary and Philosophical Society*, 1915, p. 56.

the examination of the human remains, because the people who conformed to the type in question were those buried in the most sumptuous graves and were obviously the most important people interred on this site.

In my final Report I shall set forth the data in detail and return to the discussion of these questions. All that I have attempted to do at present is to indicate what seems to me to be the natural explanation of the facts and to state the *prima facie* case in support of it.

Anthropometric Investigations in the Island of Cyprus.—Report of the Committee, consisting of Professor J. L. MYRES (*Chairman*), Dr. F. C. SHRUBSALL (*Secretary*), *and* Dr. A. C. HADDON.

THE Committee has received a report from Mr. L .H. D. Buxton, who has been carrying out investigations on its behalf. Owing to the outbreak of the European war no field work has been possible in 1914, and Mr. Buxton has been with his regiment. He has forwarded a preliminary report on further investigation of material obtained in the autumn of 1913.

Osseous Material.

From a Bronze Age site at Lapethos were secured a number of skulls and skeletons, among which two types—a long head with well-developed glabella and retreating forehead (index 73), and the ordinary short high Cypriote type (index 77 and upwards), have persisted from the Bronze Age to the present day.

Measurements of the Living.

A large number of measurements of villagers have been obtained, which will be analysed in full in later reports. The following table shows the means of over fifty individuals in each group:

Absolute Measurement.

—	Villages			
	Hagios Sergios Limnea	Levkoniko	Lapethos	Karabas
Head Length	179·6	178·9	182·7	183·8
Head Breadth	148·5	149·2	150·4	147·0
Bizygomatic Breadth	136·1	137·0	139·0	136·9
Bigonial Breadth	108·6	106·3	110·6	109·8
Nasal Breadth	33·8	35·7	34·6	34·2
Nasal Length	51·6	51·4	50·2	49·7
Upper Facial Height	67·4	69·2	67·8	65·4
Indices.				
Cephalic	82·9	83·4	82·0	80·3
Bigonial	79·7	77·5	79·6	80·1
Facial	49·5	50·5	48·7	48·1
Nasal	65·5	69·4	68·8	68·8

The stature is very uniform—1·66m. in all the villages.

A complete list of the materials available for the anthropological history of Cyprus has been made.

Exploration of the Palæolithic Site known as La Cotte de St. Brelade, Jersey.—Report of the Committee, consisting of Dr. R. R. MARETT (*Chairman*), Mr. G. F. B. DE GRUCHY (*Secretary*), Dr. A. KEITH, Dr. C. ANDREWS, Dr. A. DUNLOP, Colonel R. GARDNER WARTON, *and* Mr. H. BALFOUR.

Report of Work done in July 1915.

THE following must be regarded purely as an interim report. It covers only what was accomplished in July, whereas funds are available for carrying on the work during at least another month. When Section H meets in session, a supplementary report in MS. will be presented.

This year there have naturally occurred many obstacles in the way of archæological research, and indeed it proved impossible to resume operations at Easter, as had been originally intended. At the close of the potato season, however, when the demand for labour temporarily slackens in Jersey, there was at length forthcoming the required amount of assistance of a manual kind, Mr. Ernest Daghorn being the contractor as before. Nor, again, in the matter of skilled investigation, was it easy to arrange for the sufficiently continuous attendance of a body of helpers. Yet, despite the paramount claims of war-service, a staff was enlisted who made up for any deficiency there might be in their numbers by devotion and sheer staying-power.

In 1911 excavation proceeded along the western side-wall of the cave so as to bring to light a strip of palæolithic floor extending some 25 feet inwards.[1] It was decided this year to push still further back along this line, and, if possible, to reach the hitherto undetermined back of the cave. This is known as Working A. Further, in 1914 a trench was carried right across from the western to the eastern side-wall, a distance of about 40 feet. The portion of floor thus opened up lay eight feet from the entrance, and when work ceased last year, was flanked by precipitous walls of talus, that on the inner side being about 45 feet high, while the outer one averaged 25 feet. It was resolved, therefore, in regard to excavation in this direction, to undertake first the relatively easy and safe task of demolishing the talus on the outer side, and so clearing the cave along its whole breadth to the entrance. This was termed Working B. Lastly, it was thought desirable to attempt something on the inner side of the clearing, and to push back cautiously along the eastern wall, at any rate so far as an overhanging shelf of the live rock afforded some protection from the

[1] See *Archæologia*, lxiii. 204, where plants are given.

ever-threatening downfall of débris. This was distinguished as Working C.

To consider, then, these three sets of operations in succession. Working A has not progressed very far, but will receive more attention shortly. An additional 5 feet of penetration has been accomplished with a breadth of 6-8 feet, bringing up the total distance cleared from the entrance to 30 feet. Some very heavy quarrying has been necessary here which has involved the use of dynamite, the upper portion of the débris consisting of large blocks wedged tightly against a rather shaky roof; so that it is necessary to proceed with great circumspection. Worked flints occur sparsely at about 2-4 feet above the bench-mark from which floor-level is measured; there is very little bone to be met with. Working B has been highly successful, and the cave is now clear across its entire front. The central part of the talus which has just been removed proved to be almost sterile, but a richly implementiferous bed reaching from near floor-level to a height of 14 feet was found to exist under the ledge projecting some 12 feet outwards along the eastern side-wall. The spoil collected here in the shape of worked flints, together with cores and hammer-stones, must amount at least to a hundredweight. There was found also a good deal of bone in fair condition, ranging in size from the minute remains of lemmings to a huge knuckle-bone belonging probably to a rhinoceros. It is noticeable that a specially fine set of implements occurred near the very top of this bed, the form of these tending towards that elongated leaf-shaped pattern which has been termed 'hemi-solutrian.' Thus it would almost seem as if we had to do here with a later and more evolved product of Mousterian art than is to be found in the lower deposits of this cave; though it is true that in other places where the implementiferous bed is much thinner, extending at most to a foot or two, there was no apparent correlation between quality of workmanship and stratigraphical position. Working C has also proved very fertile so far as it has been pushed under the projecting shelf of the eastern wall, namely a distance of 27 feet from the entrance. Here the presence of a former hearth was indicated by a quantity of burnt bone. Flint was plentiful, but tended to be of coarse pattern. So too along the opposite side-wall the quality of the worked flint would seem to deteriorate as we penetrate into the depths of the cave. A sufficient explanation is probably to be found in the fact that the finer work needed the better light. Further, at the angle situated about the centre of the cave where Working C passes into Working A, the removal of a large block weighing some eight tons revealed the clearest indication hitherto encountered of the way in which the intrusive cave-filling is related to the ancient floor of occupation. At this spot a definite line can now be traced, of irregular height, but averaging 6-8 feet over bench-mark. Below this line everything is cemented together into a compact breccia, whereas above it the rock-rubbish is quite loose. At the top of the solid mass occurs a sandy deposit about 1 foot in thickness which is finely laminated and has in places almost the consistency of sandstone. This is apparently quite destitute of bone-refuse or flint-chippings, though they occur again in the looser rubbish above it. Thus it would seem as if the ancient floor

must have remained open to the winds of heaven for a long period after one Mousterian occupation, so that much dust was able to accumulate here before the cave was gradually sealed up by the stony shower from above.

At the present stage of operations, before the determinable bones have been identified, and the flint implements sorted into types, there can be nothing more to report. Enough, however, has been said to show that results have so far fully come up to expectation. Approximately 1,000 square feet of floor have now in all been cleared. Meanwhile, the sheer mass of the finds, not to speak of their excellent quality, wellnigh beggars description. This has turned out to be one of the richest palæolithic sites in Europe. It only remains to add that the Chairman and the Secretary, who have throughout been in charge of the work, could have effected little of themselves seeing how every trowel-full of cave-earth must be minutely searched through, without the intelligent co-operation of many volunteer assistants. Noteworthy among these are Mr. R. de J. Fleming-Struthers, M.A., B.Sc., of Exeter College, Oxford, who has all along sojourned by himself in the little cabin overlooking the site which the Committee has hired as a storehouse of its treasures—a storehouse that needs a faithful warden; and the Rev. E. O. James, Cert. Phys. Anthrop., of Exeter College, who laboured indefatigably during the fortnight he was able to spare for the work. Among local helpers Mr. G. le Bas, B.Sc , Mr. H. J. Baal, President of the Archæological Section of the Société Jersiaise, Mr. E. F. Guiton, to whose skill in photography the explorers of this cave owe so much, and Mrs. Symons have perhaps taken the most active part in the work so far, but many others have lent a hand as their other duties permitted. Some of the older workers, it is to be feared, have been kept away from the cave itself by the nature of the approach thereto which has of late assumed a somewhat Alpine character; though not even the present system of break-neck ladders could deter Dr. Dunlop from visiting us, while the rest have rendered manifold aid from a distance. Finally, the quarrymen have toiled with a will and have, with the rest of the party, braved danger freely; for in these trenches too there are risks to be faced, the débris having already scored one direct hit (resulting in a slashed wrist) and brought home several ricochets. Considering the conditions, however, all has gone very well, and the experience of several years' siege of this Mousterian stronghold ought to enable us to carry through our present instalment of work without any serious accident such as might mar an otherwise complete triumph.

The Committee is aware that this is not the most favourable moment at which to apply for a further grant. Moreover, it may prove at the end of the present excavation that the most profitable portions of the cave have been worked out. Nevertheless, if the funds be forthcoming, there remains plenty of useful work on which they may be spent, since the inmost depths of the cave are quite untouched. For the rest, it would be in any case well for the British Association to maintain the Committee in being, so that it may carry the work to a finish whenever opportunity serves.

Report of Work done in August 1915.

Shortly after the despatch of the Report for July a crisis occurred in the history of this undertaking. It became exceedingly doubtful whether operations must not be suspended altogether, owing to the dangerous condition of the roof. This is some forty-five feet high for the most part. Besides, it largely consists, not of live rock, but of detached blocks of granite of any weight up to ten or twelve tons, which are held in place simply by the clay that has been forced down between the fissures. A discharge of dynamite, however, cleared away everything that was not relatively stable on the side overhanging Working A. From within the breach thus effected our experienced quarrymen were then able to carry on the attack across the back of the cave, precipitating avalanches of stones by means of long crowbars and grappling-tools. As a result our workings were smothered with mountains of débris, which it has cost at least a fortnight's labour to remove. The roof, meanwhile, may be declared to be, for the time being, reasonably safe; and excavation has henceforth proceeded as merrily as before along the level of the implementiferous floor. It remains to take stock briefly of the progress of the three workings distinguished in the previous Report.

Working A, after being cleared for another six feet along the western side-wall, *i.e.*, up to thirty-six feet from the entrance, was barred by a projecting shelf of live rock. The upper part of this shelf coming first into view seemed to mark the inner limit of the cave. Nearer the floor, however, it turned out to be undercut by a cavity penetrating onwards at an angle of some forty-five degrees. How much further back this fresh extension of the cave may lead is at present a matter of pure speculation, the utmost probings having hitherto reached but ten or twelve feet, though without coming on any signs of the end. Appetite for further advance in this direction has been whetted by the discovery of implements, including one of the most perfect examples of the Mousterian 'point' hitherto obtained, in the heart of the breccia with which this annexe of the cave is packed.

Working B, which was carried across the entrance of the cave from the western to the eastern wall, was almost completed by the end of July. Up to the limit corresponding to the line of the roof overarching the entrance it has proved remarkably rich in relics of human occupation. Beyond this line, however, virtually nothing is to be found. It would seem, therefore, that the present roof marks the frontier of the ancient shelter, and that the theory of an original cave stretching from side to side of that gaping cleft in the cliffs into which *La Cotte* gives from the south must be given up. The only other possibility, and that a faint one, is that the floor descends sharply at this point; in which case remains of Man might yet be discoverable at a lower level than that which has been so far attained.

Working C has not been pushed much further back along the eastern sidewall; but, by way of compensation, the débris forming a salient between Workings C and A has been steadily reduced, so that there is now clear floor throughout from the entrance to a depth of about thirty feet. Work in this direction has revealed the encouraging fact

that the detritus is almost as rich in flint and bone at the centre as along the sides. Indeed, the sheer mass of the finds is well nigh overwhelming. The bone, moreover, is in fairly good condition; so that, for instance, a magnificent tooth of a prehistoric elephant has been rescued virtually intact. The flint implements found in the depths of the cave are on the whole of a relatively coarse and massive type, but some finer specimens occur amongst them; so that it would be dangerous to assume that this is an earlier industry which was covered up by falls of débris during Mousterian times, a shallow cave sufficing for the later generations. The simpler hypothesis is that the best pieces occur in the best-lighted parts of the workshop.

It remains to acknowledge the assistance of a staff of volunteer searchers too numerous to allow of individual mention. Mr. P. H. Brodie, however, Rhodes Scholar of Worcester College, Oxford, deserves special thanks for having contributed an unbroken month of most useful work. In addition to the helpers referred to by name in the previous Report, Mr. Nicolle, Hon. Secretary of the Société Jersiaise, and Mr. Voisin have rendered yeoman service.

The funds provided by the British Association have been ere now expended, but with the aid of the supplementary grant furnished by the Royal Society work will be continued, it is hoped, until the latter part of September. By that time a great part of the task will have been accomplished, but not all.

Appendix to Supplementary Report.

The Supplementary Report described operations up to August 31. Their end came with dramatic suddenness at 2.30 P.M. on September 3, when the roof of the cave collapsed. The recess newly discovered at the back of Working A had been opened up as regards its upper portions (which proved to be implementiferous) to a depth of fifty feet from the entrance. It was fully realised that this was a dangerous thing to do, since the roof from about twenty feet inwards from the mouth appeared to consist of loose material. Indeed, on the assumption that the cave-filling had descended through a more or less vertical funnel, the attempt was made last year to locate the top of this funnel on the north side of the cliff at a spot some seventy feet above the floor-level of the cave; and a tentative excavation at this point found loose material similar to that which seemingly composed the cave roof. It was thought extremely likely, therefore, that by undercutting to an extent of some thirty feet a column of heavy rock-rubbish at least twenty or thirty feet thick, there must eventually ensue a complete *débâcle;* and of late an anxious watch had been kept on the roof for signs of 'creeping.' The first two days of September had proved remarkably prolific in the matter of finds, and even on the morning of September 3 about forty implements and some very fine pieces of bone were unearthed; so that it was well worth while to try to carry on to the last. Suddenly dust and small stones began to drop from the roof on all sides, and it was obvious that collapse was a matter of minutes. There was just time to remove tools and other belongings when an avalanche of some five hundred tons of rock and clay descended with an overwhelming

roar, the nine persons who happened to be then at work in the cave taking to their heels with such good will that no one was hurt. When these ventured to return it was to see the sun shining down through a cavity some twenty feet in diameter on a vast pile of débris, completely obliterating the former workings.

As further falls are to be expected, work has been closed for the year. When winter weather has done its worst with the exposed sides of the chimney it will be possible to decide on the wisest course of action in regard to this as yet unexhausted site. A view from the top of the chimney makes it clear that another fifty feet or so of penetration would have reached the north side of the cliff; so that it might seem the soundest policy to break in from this side, thus immediately tapping what was formerly the back part of the cave, and avoiding the task of dealing with the débris now encumbering the thousand square feet of floor already cleared. In the meantime there is such a mass of finds awaiting determination that those who have been working here remain as busy as ever.

The Distribution of Bronze Age Implements.—Report of the Committee, consisting of Professor J. L. MYRES (*Chairman*), Mr. HAROLD J. E. PEAKE (*Secretary*), *the* Hon. JOHN ABERCROMBY, Mr. E. C. R. ARMSTRONG, Dr. G. A. AUDEN, Mr. HENRY BALFOUR, Dr. GEORGE COFFEY, Mr. O. G. S. CRAWFORD, Professor BOYD DAWKINS, Dr. H. S. HARRISON, Mr. E. THURLOW LEEDS, Dr. R. R. MARETT, Sir CHARLES HERCULES READ, *and* Professor W. RIDGEWAY.

No meeting of the Committee was held during the year, but the Secretary attended the meeting of the Association Francaise, held at Le Havre in July, 1914, and through the courtesy of Dr. F. Gidon, its President, was enabled to bring the objects of the Committee before the Section of Anthropologie. The idea was received very cordially by those present, especially by M. A. de Mortillet, and many offers of assistance were received. The order for the mobilisation of the French army, which was issued the following day, has prevented any further communication with our allies on this subject.

Owing to the war it has been impossible to proceed with the formation of the card index; nevertheless a considerable number of sketches and notes have been furnished by Miss Morey, Miss Minns, Lieut. O. G. S. Crawford (9th Batt. the Royal Berkshire Regt.), and 2nd Lieut. G. A. Curnock (4th Batt. the Rifle Brigade), while further information is expected shortly from Mr. W. Dale, F.S.A., and Mr. E. Thurlow Leeds. These notes refer to specimens in the museums of Newbury, Southampton, and Carisbrooke, as well as to those in several small private collections.

Cards for the index, a box in which to store them, callipers, and scales are now needed, and the Committee seeks reappointment with a grant of 10*l*.

Excavations on Roman Sites in Britain.—Report of the Committee, consisting of Professor RIDGEWAY (*Chairman*), Professor R. C. BOSANQUET (*Secretary*), Dr. T. ASHBY, Mr. WILLOUGHBY GARDNER, *and* Professor J. L. MYRES, *appointed to co-operate with Local Committees in Excavations on Roman Sites in Britain.*

THE Committee was reappointed in September, 1913, with a grant of 20*l*. This sum was divided in equal shares between (1) the Committee of the Abergele Antiquarian Association, which in conjunction with the Cambrian Archæological Association is exploring the hill-fort in Parc-y-meirch Wood, Denbighshire; and (2) the Committee representing the Society of Antiquaries and the Shropshire Archæological Society, which is excavating the Roman town of Uriconium (Wroxeter).

Owing to the early date fixed for the delivery of reports in 1914 it was not possible for the excavators to present the results of work done that summer in time for the Australian Meeting, and the Committee therefore submitted an interim statement, explaining that fuller accounts of the results obtained on both sites would be presented in 1915. These are appended to the present Report.

(1) *Dinorben.* Previous discoveries on the Denbighshire site were described by the excavator, Mr. Willoughby Gardner, in papers laid before the British Association in 1912 and 1913. The work of 1914 threw further light on the extent and character of the fourth-century occupation, but was chiefly directed to tracing the growth of the fortifications and endeavouring to correlate the successive entrances, ramparts, and ditches. It is now clear that the main south-east gate, with its successive roadways and guard-houses, was not the original entrance; an earlier gate, destroyed by fire, has been found embedded in the stone rampart a few yards to the east, and the road belonging to it has also been laid bare. An early rampart, corresponding with this gateway in its mixed stone-and-timber construction and showing still plainer evidence of a great conflagration, has been traced under the guard-houses and main rampart on the west of the south-east entrance. The dissection of the enormous main rampart has been continued and the finding of revetment-walls gives a clue to two, if not three, periods of construction. The ditches which Mr. Gardner in his previous Report explained as perhaps constructed in the first century of our era, when native forts were hastily strengthened in view of Roman attacks, have been further explored; wherever examined they show the same phenomenon, a filling of freshly quarried stone, the unmistakable *débris* of a stone rampart overthrown soon after its erection. Owing to the dearth of pottery and other characteristic finds, Mr. Gardner does not at present assign dates to the successive stages in the history of the stronghold. He has shown much ingenuity and patience in surmounting the natural obstacles presented by this exceptionally difficult site, and his plans, sections, photographs, and records of levels are full and accurate. The Committee hopes that he may be enabled to continue this very promising investigation.

(2) *Uriconium* (Wroxeter). The scheme for the systematic excavation of this Roman town was laid before the Association at the Birmingham Meeting. The direction of the work is in the hands of Mr. J. P. Bushe-Fox, who had previously worked with distinction at Corbridge and at Hengistbury Head. Two detailed and well-illustrated Reports on the work of 1912 and 1913 have been issued by the Society of Antiquaries, and that for 1914 is in the press; the appended statement gives an interesting summary of the results gained during these three seasons in an undertaking that may fairly be described as of national importance. The Committee notes with satisfaction the rapid progress that is being made in determining the sequence and dating of Romano-British pottery, thanks to the careful records of stratification kept in recent years at Corbridge, Wroxeter, and other sites.

The Committee asks for reappointment and for a renewal of its grant.

Reports to the Committee.

I.

Further Excavations in Dinorben, the ancient Hill Fort in Parc-y-meirch Wood, Kinmel Park, Abergele, North Wales, during 1914. *By* Willoughby Gardner, *F S.A.*

The excavations in this hill-fort by the Abergele Antiquarian Association and the Cambrian Archæological Association, recorded in Reports of the British Association, 1912, pp. 611-12, and 1913, pp. 231-36, were continued during the summer of 1914. The excavators were again greatly assisted by a Research Committee of Section H of the British Association, whose Secretary, Professor R. C. Bosanquet, spent two days upon the site, and by the Association's grant towards the cost. Work occupied about six weeks; ten labourers and a foreman were employed, as before, and much help was given by amateur assistants. To Colonel Hughes, the owner of the site, warm thanks are again due for continued interest and assistance in numerous ways.

Operations were first directed to the massive dry masonry wall discovered in 1913, running crosswise in the thickness of the main rampart, 18 feet to the E. of the S.E. entrance. As the rampart stood 9 feet high and was 28 feet thick at this point from facing wall in front to casing wall at back, and both these walls were buried behind a further thickness of *débris*, the work was laborious. The bulk of the rampart consisted of rubble-stone, but approaching the ground-level many large slabs and roughly squared stones were encountered near the cross-wall. In places, especially towards the inner side of the rampart, quantities of burnt stone and calcined lime were also found, with fragments of charcoal here and there. At the foot of the wall a well-gravelled surface was uncovered, trodden hard like a road. The cross-wall was laid bare to its foundation, standing 8 feet high for a straight length of 16 feet. At its outer end this massive wall was found to be cut at right angles by the later built facing wall of the rampart, continuous with the side wall of the pre-

viously excavated S.E. entrance; at its inner end it turned off sharply 2 feet to the right and then curved round in its first direction for several feet further, forming a shallow recess. There was a groove from top to bottom of the wall at 11 feet from its outer end, 1 foot 6 inches wide and 1 foot deep, and at the foot of this groove there was a hole in the ground stiffened by stone slabs; this groove and hole were evidently for a wooden post built in at the time of construction. At the corner where the wall turned off 2 feet there was a similar post-hole in the ground, 1 foot 6 inches wide, apparently constructed of stones placed within a larger excavated hole. But both these post-holes were difficult of examination owing to the dangerous way in which the wall bulged over them. Opposite to these two post-holes, at a distance of 9 feet from the wall, two other large holes, cut out of the rocky ground, were subsequently unearthed; both contained many flat stones, either set upright or fallen within them, as if for post-holes; there were small pieces of charred wood, possibly remnants of a post, at the bottom of the N.W. hole

The gravelled road lying between these four holes was traced in an outward direction running beneath and beyond the later facing wall of the rampart; in an inward direction it also continued beneath the back walls of the previously excavated guard-houses and two inner casing-walls of the rampart. It had a width of about 9 feet throughout its course. Curiously, no side wall was found on the W. side of this roadway; one big upright slab embedded alongside the outer post-hole here seemed to be the only stone of such a wall *in situ*. But apparently many of the stones of a former wall were those which were found lying upon the roadway; others had probably been quarried for later constructions.

It seems clear, therefore, that the excavations have brought to light a ruined entrance of still earlier date than the successive entrances unearthed 18 feet W. in 1912 and 1913. This earlier entrance seems to have suffered forcible destruction by the throwing down of its western wall into the passage. Moreover, the quantities of burnt stones and burnt lime, with some charcoal, found in the lower strata of its ruins, point to a conflagration at the same time.

It was noted that the burnt lime layer above the roadway extended beneath the foundations of the two successive guard-houses on this side belonging to the previously excavated S.E entrances. The only relics found in this early entrance were pieces of broken bone of *Bos* trodden into the roadway, some charcoal, a broken 'pot boiler,' and a small bone 'scraper'—none of which are datable.

This discovery under the rampart on the E. side of the first-found S.E. entrance made it desirable to examine the rampart on its W. side; and this more particularly because ditches 1 and 2 here were found, upon excavation last year, to curve inwards and to end at some distance before reaching the entrance. The rampart at this point is unfortunately very large and four big trees were growing upon it; these were felled and removed; but as the excavation of such a mass of material by barrow and plank in a difficult position would have been very laborious, it was decided to employ a ropeway carrier of the 'Mond'

type (so successfully used in Egyptian excavations), modified to suit the present site. This only came to hand towards the close of our time and did not work upon the steep slope, necessitating a return of portions to the makers for alteration.

Meanwhile a beginning was made upon this rampart from the back, some 25 feet from the S.E. entrance. Here, in the interior area of the hill-fort and up the slope to the present crest of the rampart, fragments of black and red pottery were unearthed, at a depth of about a foot, similar to that found on the same horizon elsewhere. Then burnt lime began to appear, like that discovered in the earlier entrance to the E.; and, finally, a mass of burnt stones and lime was cut through, some 5 feet thick against the rampart and tapering to nothing at a distance of 15 feet towards the interior area of the fort. Near the bottom of this mass and just above original ground level, a quantity of clay, burned red and hard almost like brick, was revealed, and mixed with and under this a great deal of charred wood; some of the wood was as large as if the remains of considerable timbers. Here again, therefore, there would appear to be traces of some great conflagration, apparently belonging to the same period as the lesser traces of fire found in the early entrance. On following up these deposits of burnt lime towards the E., they were found to run beneath the foundations of the guard-houses on this side belonging to the entrances excavated in 1912 and 1913; again, therefore, marking an episode at some distinctly earlier date. Further explorations beneath this great rampart by aid of the rope carrier are looked forward to with interest.

Turning again to the main rampart N.E. of the S.E. entrance, a cutting was made through it at a point 105 feet distant from the entrance. Its dry masonry outer facing wall, still standing 3 feet high, was discovered beneath fallen *débris* in 1912; its inner face was now found to be marked by a line of big stones with some pitching above, showing a rampart 23 feet thick. The core was of mixed construction and material, and apparently contained an earlier rampart, 15 feet thick, revetted also on its inner side with a stone wall 3 feet high.

Before leaving the neighbourhood of the S E. entrance excavated in 1912 and 1913, the gravel roads leading therefrom were further investigated. It will be remembered that three superincumbent roads were found in the entrance passage. The upper one, proved by relics to be in use in the fourth century, ran down the slope towards the E.S.E.; at a distance of 45 feet from its outermost post-holes it crossed over the end of ditch 1, the whole length of which had been filled and hidden from sight by stony *débris* at some earlier date. The second road could not be distinguished far beyond the entrance passage, and may have been a local reparation only. The lowest of the three roads, however, was found to run S.S.E. till it was crossed and covered by the end of rampart 3. This lowest road was from 12 to 15 feet wide and was made of small blue gravel laid, 6 inches thick at its centre, upon the original ground surface. Neither of these roads outside the entrance had any 'pitching' below or any curbstones at their sides. We thus obtain relative ages for ditch 1 on the E. side and rampart 3 on the W. side of the S.E. entrance. Noteworthy relics unearthed in these investigations

were a bronze hook and eye bracelet, with dot and ring ornament, found 1 foot deep, and a small bronze crozier-shaped object, possibly the handle of a key, from about the same depth.

Attention was next directed to the N. end of the stronghold, in continuation of the work previously done there. The buried entrance at the N.E. was further investigated. The position of this entrance was marked down in 1912 by the discovery of a stone-lined post-hole, and was further proved in 1913 by the excavation of a rock causeway leading up to it between the ends of two ditches. The ramparts hereabouts proved to be very ruinous, consisting of little more than rubble-core, with their facing-stones and much of their bulk thrown down into, filling and completely covering up, the ditches in front. When the *débris* which choked this entrance 5 feet deep was removed, it was found to be a passage about 10 feet long and 10 feet wide at right angles through the rampart. No side walls were found; presumably they had been removed when the entrance was destroyed; but four post-holes were unearthed, one pair at either end of the passage. Of these, the one at the right hand on entering was 2 feet deep and stone-lined, and the one on the left was cut in the rock and shallower; at the inner end of the passage, the one on the left was 2 feet deep cut in the rock, and the one on the opposite side shallower; in the deeper one charred wood was found. The roadway ascending steeply through this entrance passage was of rock, the interstices of which were filled in with small blue gravel.

At some date subsequent to the destruction and choking up of this entrance, another and a smaller one seems to have been cut through the *débris*. This was 10 feet long and only 4½ feet wide; portions of its side walls of dry masonry remained standing; two pairs of small shallow post-holes were found cut in the rock, one pair at its entrance and one pair half-way through its length. The roadway through this entrance appeared to be made of large rough gravel, overlaid several inches thick upon the rocky floor of the earlier entrance. At the inner end of this later entrance, the side wall turned at right angles to the left and was traced as a casing wall to the inner side of the rampart for some 12 feet; at this point it was crossed by another curving-wall built at a higher level. The only relics found upon the floors of these two entrances were many broken bones of animals consumed for food, some 'pot boilers,' and some charcoal, in this as in other respects corresponding with the lower floors of the S.E. entrance. At heights varying from 2 to 3 feet above the lower floor, however, or 2 to 2½ feet deep in the loose *débris* blocking the ruined entrance, fragments of Roman pottery, iron nails, Roman glass beads, and two coins of Constantine, all relics of the fourth century occupation of the stronghold, were unearthed. At a little above the same level, some foundations of a wall-facing ran across the outer end of the passage, showing that at this period there was no entrance here.

Following up the roadway into the hill-fort, some 60 square yards of the interior area were next explored by careful riddling. Considerable quantities of Romano-British relics, including several coins, all similar to those found close by in 1913, were unearthed. These relics were

again very near to the present surface; they were for the most part covered by a foot of humus only.

The main rampart at the S.W. side of the hill-fort was then investigated, together with some 55 square yards of the interior area adjacent —the whole of the latter with the riddle. Here, what had come to be known as our ' relic bed ' was again encountered, between 1 and 1½ feet below the present surface. The bed extended from the level interior area almost up to the crest of the rampart, although objects upon the flat were far more abundant than upon the slope of the rampart. The relics found were practically a repetition of those already recorded from a similar level elsewhere in the hill-fort, with certain additions. These additions included part of a bronze penannular brooch, an interesting bronze gilt ornament (possibly a plate brooch), several earrings and other articles of coiled bronze wire, a bone toggle, a very small iron sickle, part of a horseshoe, a good flint scraper, and, among pottery, fragments of a red incense bowl with fringed rim, fragments of painted white *mortaria* with hammer-head rim, fragments and a rim of ' calcite ' or ' vesicular ' ware and several portions of black bowls mended with iron rivets; the latter would seem to show that even the common pottery used here was imported from a distance, or it would hardly have been worth the trouble of repair by riveting.

The rampart here was then cut through from back to front; there was no facing-wall, only a few stones in line which may have been the remnant of one. Some 30 feet behind these stones a low wall apparently marked the back of the rampart. The core was again found to be of mixed material, mostly dry rubble-stone with thick layers of clay in places; its construction seemed to show a later and a larger rampart covering an earlier and a smaller one. At a point 5 feet in front of the present crest and 4 feet below it, the top of a parallel dry stone wall was encountered; this was excavated and found to stand 5 feet high; it was probably the back wall of the earlier rampart. Further, at 11 feet behind this wall and 10 feet below the present crest, the top course of yet another parallel wall was discovered on the closing day of our work; this would seem to belong to a still earlier structure. We regretted the necessity of postponing its exploration, which will require the removal of a great weight of material in order to reach it.

Many fresh cuttings were also made at various points in front of the rampart, in further investigation of visible ditches and ramparts and in search for other ditches suspected but hidden from view by *débris*. Two long cuttings approximately W.S.W. (on which side of the hill-fort it will be remembered that the main rampart is entirely thrown down) revealed three parallel ditches cut in the rock; two of these had been hidden from sight by fallen *débris*. These three ditches, like others previously excavated, were filled, the first completely and the second and third less so, according to the slope of the hill-side, with clean dry rubble mixed with some larger wall-facing stones. These stones lay upon the rocky bottoms of the ditches with hardly any silting below them, again showing that the main rampart must have been thrown down soon after these ditches were cut.

Part of the rocky berm excavated between the site of the main

rampart and the first ditch revealed an unexpected layer of clay and gravel beneath the superincumbent stones; this was dug through, 2 feet thick, and beneath it, in each section, another and an earlier ditch cut in the rock, 5 feet deep and 7 feet wide, was brought to light. This ditch again was filled nearly to its brim with dry rubble stones, beneath which there was 1 to 3 inches of silting on the bottom of the ditch. These rubble stones must represent the ruins of a former rampart above of corresponding age; and the probable foundations of such a rampart were seen in the westernmost cutting.

In one of the cuttings made in 1913 to the S.S.E., which had revealed previously hidden first and second ditches cut in the earth, some curious features were then noted beneath the second rampart; these called for further investigation when timber could be obtained to make the deep excavation safe. This year the cutting was dug deeper, with the result that below the artificially laid clay of the second rampart another and an older wide ditch, partly cut in rock, was here also brought to light; this ditch was likewise found to be half filled with dry fallen rubble mixed with a few larger wall-facing stones, again showing the existence and the destruction of a stone rampart behind it of approximately similar age. Unfortunately, no datable relics were found in any of these earlier ditches or in connection with the earlier wall-facings.

To sum up the work done in 1914. In addition to the finding of many relics and the gaining of further information about the occupation of the stronghold in the fourth century A D., many important fresh discoveries have been made, which give glimpses of the structure of a previously destroyed hill-fort or hill-forts. To follow up these discoveries under huge masses of difficult and shifting stony *débris*, and to link up the facts already obtained to one another, much labour will have to be incurred. But the investigators are looking forward to continuing the work after the cessation of the War. Detailed records of excavations made in 1914 have been preserved, as before, in the form of plans, sections, and photographs.

II.

Excavations at Wroxeter, on the Site of the Roman town of Uriconium, 1912-1914. *By* J. P. BUSHE-FOX, *F.S.A.*

The Society of Antiquaries, in conjunction with the Shropshire Archæological Society, carried on extensive excavations at Wroxeter during the years 1912, 1913, and 1914.

Wroxeter, the ancient Viroconium or Uriconium, is situated on the east bank of the Severn, between five and six miles south-east of Shrewsbury. The lines of its walls can still be traced enclosing an area of about 170 acres, and the town must have been an important centre in Roman-Britain, as it stood at the junction of two of the main roads, viz., the Watling Street from London and the south-east and the road from the legionary fortress of Caerleon in South Wales. There were also other roads running from it into Wales and to Chester. The town is referred to by the Ravenna geographer as Viroconium Corno-

viorum, and was probably the chief town of that tribe which inhabited a district including both Wroxeter and Chester.

That the site was inhabited soon after the invasion under Claudius in 43 A.D. is evident. Coins and other objects of pre-Flavian date have been met with in some quantities, and there are tombstones of soldiers of the XIV. legion from the cemetery. This legion came over with Claudius and left Britain for good in the year 70 A.D. Wroxeter, situated on the edge of the Welsh hills and protected from attack on that side by the River Severn, would have formed an admirable base for operations against the turbulent tribes of Wales, and it is more than likely that it was used as such in the campaigns undertaken by Ostorius Scapula in 50 A.D. and by Suetonius Paulinus in 60 A.D.

The Welsh tribes were finally subdued before the end of the reign of Vespasian, and, the country becoming more settled, Wroxeter appears to have ceased to be a military centre and to have grown into a large and prosperous town. It is in this period, namely the last quarter of the first century A.D., that the occupation began on the part of the site recently excavated. Very little of the earlier buildings remained, as they all appear to have been built of wood and wattle-and-daub. In the second century more substantial houses were erected, and in the course of the excavations the following buildings were uncovered. In 1912 four long shops with rooms at the back and open fronts with porticos on the street. In 1913 a temple which must have been of some architectural pretensions and contained life-size statues, of which several fragments were discovered. In 1914 a large dwelling-house consisting of a number of rooms with a large portico on the street and a small bath-house at the south side. The porticos of all these buildings formed a continuous colonnade by the side of the street. At the back of the large dwelling-house another structure was discovered. Unfortunately, it could not be entirely explored, as its west part was beyond the reserved area. It consisted of two parallel walls, 13 feet apart, which enclosed an oblong space with rounded corners, 144 feet wide and 188 feet long, to the furthest point excavated. No other building of this form appears to have been found elsewhere, and it is difficult to say for what purpose it was used, especially as part of it is still unexcavated. It is possible, however, that it may have been a place of amusement for games, bull-baiting, &c., and that the two parallel walls held tiers of wooden seats.

The buildings that faced the street had been altered and rebuilt several times, the mixed soil being as deep as 8 feet to 10 feet in places, making the work of excavation very slow and laborious. For instance, in 1914 there was evidence of at least four different periods of buildings on the same site. In the early period there were wood and wattle-and-daub houses. Over the remains of these in the first half of the second century three long buildings with open fronts or porticos similar to those found in 1912 were erected. About the middle of the second century these three buildings were incorporated in one large house with corridors, two courtyards, many rooms, some with mosaic floors, and others fitted with hypocausts. A bath-house with cold baths and hot rooms was situated at the south-west corner. At a

later period this dwelling was considerably altered, several of the rooms were swept away, and the central part of the building turned into one large courtyard with corridors on three sides. Two new hypocausts were inserted and extra rooms and a long corridor or verandah built at the back. Water was supplied to the houses by a water-main at the side of the road. By shutting sluice-gates it was possible to divert the water into side-channels, which ran through the houses flushing their drains, and discharged at the back into the river. Eleven wells were found during the excavations, varying from 10 feet to 12 feet deep and stone-lined.

A number of crucibles and some unfinished bronze castings, &c., have been met with, showing that metal-working was carried on on the site. There was also evidence of other industrial processes, such as enamelling and working in bone. A very large number of small objects have been discovered during the excavations, such as cameos, engraved gems—some still set in finger-rings—many brooches of different metals, enamelled ornaments, and a quantity of interesting articles in different metals, bone, glass, &c.

The great quantity of pottery found may be judged by the fact that upwards of 900 potters' stamps on Samian ware have been recorded. The coins number between 1,200 and 1,300, among them being a few British varieties. No coins later than the end of the fourth century have as yet been met with, and the town does not appear to have been inhabited after that date. What was the cause of its destruction or desertion is as yet uncertain, but it is hoped that future excavations will solve the problem.

Detailed accounts of the excavations are printed in Reports of the Research Committee of the Society of Antiquaries of London, Nos. 1, 2, and 4.

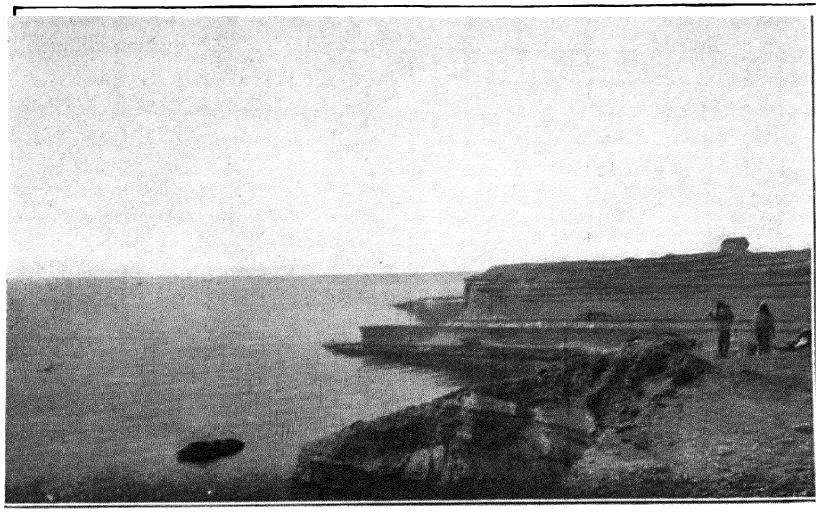
Archæological Investigations in Malta.—Report of the Committee, consisting of Professor J. L. MYRES (*Chairman*), Dr. T. ASHBY (*Secretary*), Mr. H. BALFOUR, Dr. A. C. HADDON, *and* Dr. R. R. MARETT.

DURING the year excavations have been carried out by Dr. Ashby in the ruins at Xrobb il Ghargin, and by Dr. G. Despott at Tal Herba and the Burmeghez Fissures. Reports on these excavations are appended. The whole of the grant has been expended on this work. The Committee ask to be reappointed with a further grant of 10*l.* for the purpose of carrying on the investigation of other important sites in the island.

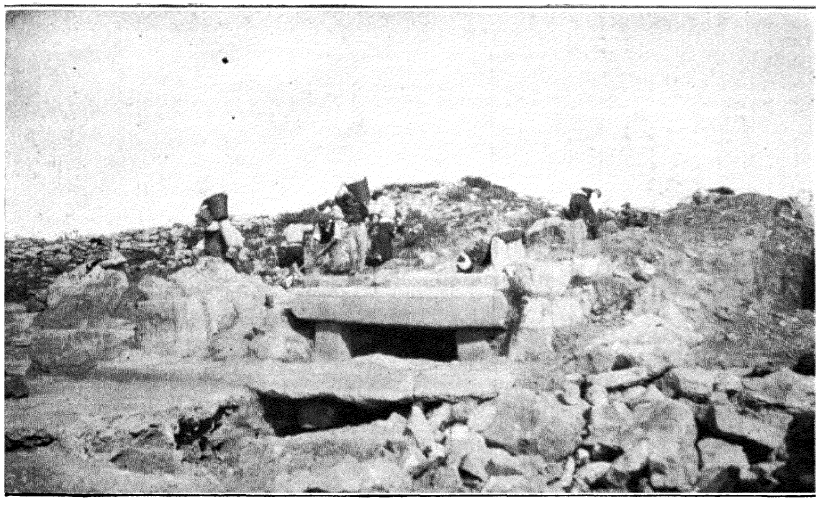
I.

Xrobb il Ghargin. By Dr. T. ASHBY.

The ruins of Xrobb il Ghargin are as beautifully situated as any in Malta. The building which they represent was undoubtedly a temple or sacred edifice of the eneolithic period, and its site is an exceptional one, on the edge of the cliffs near the extreme S.E. point of the island.



Coast Site of Building.

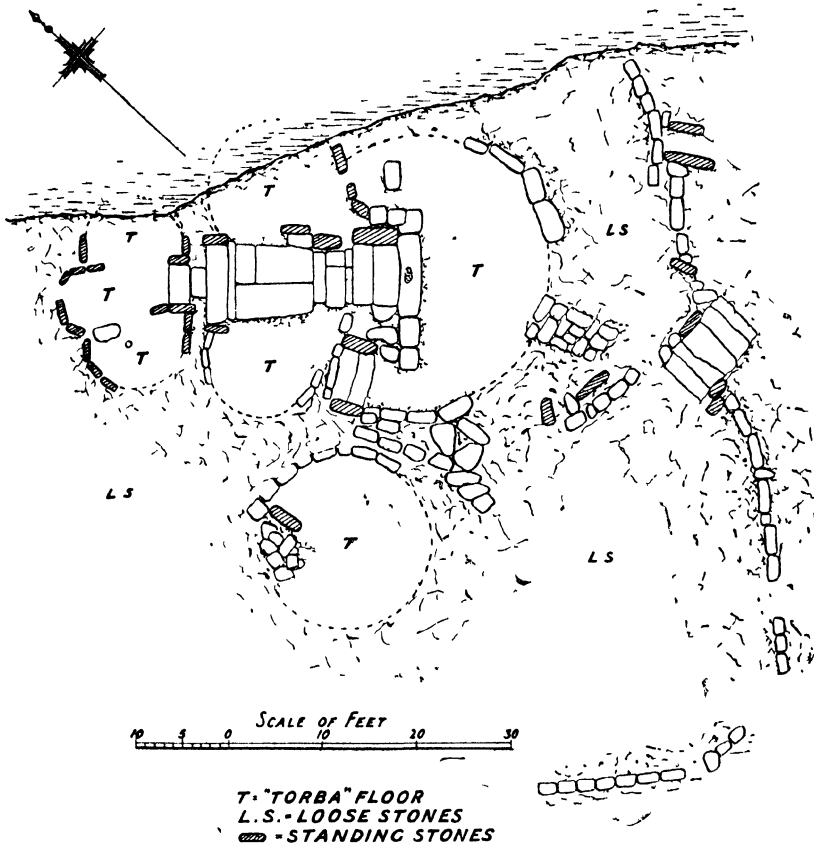


Room A, looking North-west.

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To the N.E. runs a line of exceptionally white cliffs, which terminate in the treacherous reef of the Munshiar (saw); to the S. is a much smaller point of softer and yellower rock running eastward, in the upper strata (the harder white strata begin to dip), and followed to the S.E. by a flatter bit of coast, guarded by a disused redoubt and tower. Then the deep indentations begin again, and continue until Delimara Point,



Plan of Neolithic Remains at Xrobb-il-Ghagin on the East Coast of Malta, surveyed in May 1915.

with its lighthouse, is reached. In the bay between the Munshiar and the redoubt, about 150 feet above the sea, is the building which forms the subject of the present paper. All the rock of this part of the island is soft, and the indentations are continually becoming deeper, while the cliffs are much undercut. A considerable portion of the edifice has thus fallen into the sea, and the collapse of the rest may not be very far distant, as it is deeply undermined. The existence of the ruins was discovered by Mr. Carmelo Rizzo, P.A.A., who

noticed the presence of a considerable depth of red soil upon the light-yellow rock.

Excavations were undertaken in December 1914 by Captain Laferla of the King's Own Malta Militia, who uncovered the most important portion of the building. The plan was not completed, however, owing to lack of time, and supplementary work proved necessary. This extended over ten days in May 1915, under my supervision.

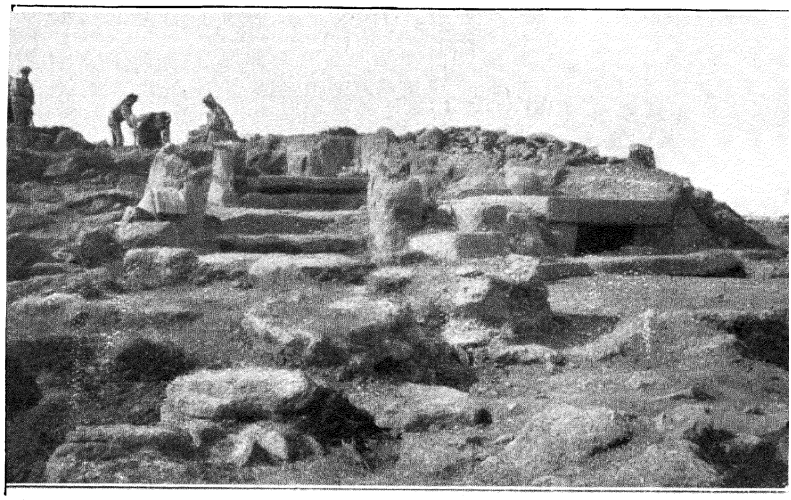
The remains of the structure need, as they stand, a comparatively brief description. We have, it seems, before us a sacred building of the eneolithic period—contemporary, that is, with Hagiar Kim, Mnaidra, the Gigantia, and the other megalithic edifices of the Maltese islands Owing to its situation it does not altogether conform to the normal plan, as far as we can judge from the existing remains; though the fact that much of it has fallen into the sea must always be taken into account.

We seem, then, to have before us a central portion, consisting of (1) a semicircular chamber with a torba floor, with a shrine facing S.E. at its N.W. extremity; (2) a passage paved with large slabs of stone, which are on the level of the top of the low niche of the shrine, and are indirectly reached from the chamber A by a flight of steps leading into the chamber D on the S.W. side of this passage; (3) a chamber at the N.W. end of this passage; (4) another chamber beyond D again. Mr. R. V. Galea has noticed that in this building only of the megalithic monuments of Malta the main chambers are semicircular and not elliptical. On the N.E. side we have only the beginnings of walls, from which we cannot do more than infer the existence of other chambers here. But from the examination of the rest, it seems almost as if we might recognise in the central portion an arrangement identical with that which is familiar to us in the larger Maltese sanctuaries—two elliptical chambers joined together by a passage across their shorter axes, with a niche at the end of this passage, in a straight line with the main entrance.

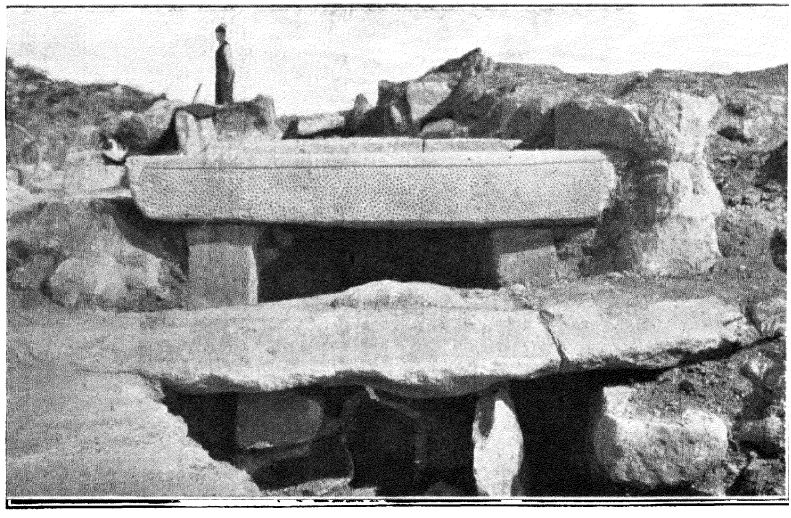
The portion of the building to the S.E. of A is constructed on a fairly steep slope, and traces of steps connecting its different portions may be seen at various points. For the rest, however, it is much ruined, and the same is the case on the N.

We may now proceed to describe the building in somewhat greater detail, beginning at the S.E. boundary-wall. This wall follows an irregular curve, and is built of rough stones of no great size. A considerable amount of pottery and some good flints were found just outside it (some in a burnt earth layer 1·00 down) as though they had been thrown out here from the interior of the building, the flints more especially at its extreme south point, where it turns to run south-west. Somewhat scanty remains of two flights of steps ascending through it to the interior of the building may be seen at two different points. They both served as means of communication with the upper part of the building, and apparently led to a passage which ran outside the lower (S.E.) wall of A.

There are a good many standing stones in this portion of the building, none of them being preserved to any great height, so that



Boom A and Steps to D, looking North.



Niche in A.

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the arrangement of this part is not very certain. But there was no doubt a massive terrace wall below Room A with vertical slabs once preserved to some height, and forming a façade; and here, as elsewhere, there were, besides, tie-slabs at right angles to the direction of the façade. This façade had, as is usual, footing blocks, which may be seen at *a*, where they are 0·65 m. wide. Behind it was a space filled with loose stones, and then came the inner wall of A. The total thickness of this wall, without the footing blocks, was thus not less than 2·95 m.

The most important part of the building is, as we have said, Room A. It is a semicircular room some 10 m. in diameter; the inner wall, the lowest stones of which are preserved, was about 0·65 m. thick. On the S.W. side there is a line of low slabs 0·55 m. wide along its inner side, which possibly served as a seat, as they are 0·28 m. above the floor.[1] The room has a torba floor 0·10 m. thick; under it are stones and earth. In the earth a considerable amount of pottery was found, which is naturally of considerable importance for the determination of the date of its construction. The rock-bottom is 0·67 to 1·00 m. down.

The chord of the semicircle is occupied by the shrine, a dolmenic niche resting upon small pillars, and only 0·30 m. in height. It faces 35° E. of S. The covering stone measures 1·91 m. in length by 0·81 m. in depth, and 0·28 m. in thickness; and the vertical front, which is slightly convex as regards its length, is finely pitted with round holes. The niche itself is curved, and measures 1·00 in width and 0·75 m. in depth; the wall is built of small stones, the joints of which are formed of clay, which is still well preserved.

In the niche was formed a large circular ball of stone, 0·39 m. in diameter, one side being slightly flattened.

In front of the niche is a low threshold stone, broken into three pieces, and measuring 2·50 m. in length, 0·90 in maximum width, and 0·20 in thickness. The front edge of it slopes away slightly towards the torba floor. In the centre of this stone is a rectangular base measuring 0·47 m. long, 0·24 m. wide, and 0·08 m. high. The vertical front of it shows signs of pitting, and it has no doubt been a pedestal to carry some sacred object which was revered at this shrine. On each side of the shrine the threshold is continued by another block, that on the west having an incised line along the top of the vertical face. The total length is thus 4·19 m. Behind and beside these blocks are standing stones. To the S.W. of the shrine is a flight of three steps 1·58 m. wide, with a raised threshold block between the second and third step leading up between vertical slabs (and therefore probably roofed), to Room D, which is paved with torba,[2] the rock being about 0·47 m. down. The lintel block of the shrine has the upper surface smoothed; in it are two very shallow depressions 0·13 m. apart and 0·035 m. in diameter, which obviously bear some analogy to the pairs of holes connected by a small tunnel, which are frequently met with in the thresholds of the megalithic buildings of Malta. Beyond

[1] 15° E. of S. is a foundation of stones projecting 0·90 and 1·25 wide.

[2] In it was a layer 0·04 m. thick of burnt earth, with a few small pieces of wood.

this is another slab, and then a raised threshold block, exactly like that at *c* in Corradino South. Then comes a threshold divided into three parts, at each end of which are small, slightly raised areas[3] upon which wooden door posts may have rested; and then comes a smaller slab. So far, at least, vertical slabs are preserved on the N.E. side of this slab pavement, and their presence may perhaps be supposed on the N.W. The original height cannot be determined, as those on the N.E. are truncated; but it would seem clear that there was originally one upper dolmenic niche above the shrine as it is preserved. Beyond this point there is a recess on the N.E. side measuring 0·82 × 0·46 (the floor block of it is 0·21 thick and lies above the slab pavement of the passage, and a burnt earth layer was found upon it).

Behind and beyond it is the torba floor of another room, the greater part of which has fallen down the cliff, on the level of the main slab pavement; and here is a strongly marked burnt layer with charred wood in it, while on the S.W. the torba floor of D must originally have come up to the slab pavement of the central passage. This is here composed of two large slabs 0 22 m. thick, running S.E. and N.W. Under them is a torba floor (scanty traces) 0·53 m. below the bottom of the block.

After a space filled with broken stones, we reach two low steps. Between it and the upper block is a space 0·12 m. high, closed by small stones; then comes the upper block. There is a vertical slab on each side. The passage then narrows considerably, still having vertical slabs on each side. At the point where it does so, the paving block of the passage has a raised area 0·77 m. long, 0·36 m. wide, and 0·06 m. high, which, no doubt, served as a base for a statue or baetylus.

Beyond it is a smoothed block with a fine small edging round it, and a smoothed vertical face on the N.W. which must, however, have mainly been covered by torba. This narrow passage leads into another room with a torba floor. The side walls are of vertical slabs, but do not go down within 0.30 m. of the floor-level, being supported by a base of stones and earth. The block *b* is *in situ*, and in the recess on the S.W. of it a round slab of stone 0·45 m. in diameter and 0·05 thick was found lying on the torba floor. The block *c*, on the other hand, has fallen from the side wall.

The exploration of the mound behind (1) led to no definite result; and it is probable that the building did not extend further in this direction, that the mound was piled up to support the back of (1), and that the stones to the W. of (1) have simply fallen.

A little pottery was found about six feet down on an irregular sloping block of stone, which is probably a part of the rock. The soil has apparently been washed down the slope in the course of centuries. At the lower extremity of it is a straight wall of small stones, no doubt a field-wall, certainly having no connection with the megalithic building. To the S.W. of the room is an area paved with torba, which rests

[3] 38 × 24 c.m. on S.W. 45 × 17 on N.E.

directly on the rock, which is 0·15 below its upper surface. It is confined on the N.W. by a curving wall, but its limits towards the S.W. cannot be fixed.

To the S. of the building is a well. Lower down the slope are some very uncertain traces of walls of which nothing definite could be made.

II.

Tal Herba and Burmeghez Fissures. By Dr. G. DESPOTT.

Tal Herba Quarry. This quarry, which is known to the people of the locality as 'Il Barrira tal Herba' or 'Il Barrira tal Guzzu,' is situated on the right side of the road which leads from Luca to Micabiba or Mkabba, and is only about 200 yards away from the first houses of this last village. At present it is no longer a quarry, but has been filled with red earth and is being used as a field where crops are regularly grown. The fissures in this quarry are two, which we will call Fissure 1 and Fissure 2.

Fissure 1.—This fissure was dug by me, assisted by my friend Mr. Carmelo Rizzo, the Engineer to the Public Health Department. As could be judged from a section of it which still remained when we first saw it, it was bell-shaped, very like the surface fissures at Burmeghez, which place is only at a short distance to the N.W. of this; human bones having been found in these fissures we naturally expected to find the same in the present one too. The original opening to this fissure was also similar to those of Burmeghez, being at the top, and had a diameter of two or two and a half feet. (When I say at the top, I mean in a vertical and not in a slanting position, like many of the openings to the other fissures.) The depth was a little over six feet, and its greatest width eight feet. At a distance which varied from two to three feet from the opening it was filled with the usual red earth, this being of a lighter colour at the surface.

On our arrival at the place the workmen at the quarry presented to us some loose bones which looked very like heads of the limb-bones of an elephant. As these, however, were not found by us *in situ*, we decided to discard them, knowing, moreover, that such bones could be secured from a locality near Mkabba, known as Gaudia fissure. The first piece of bone we found in our digging was the right part of a mandible of a pig (*Sus scrofa*). A few inches further down the remains of a stag (*Cervus elaphus* var. *barbarus*) were found, and these continued till a depth of about a foot; together with these was also found a part of a marine bivalve (*Tapes decussata*).

At this place, *i e.*, at about one foot from the surface, a plastron from a carapace of a tortoise, probably a fresh-water species, was found, and to a depth of more than two feet these remains continued; amongst them we could identify six humeri of the same side, showing thus that the remains belonged to at least six individuals, and these must have varied in size from six to say eight inches. Some of the plastrons were still adhering together, but as they were so very friable and the earth of a rather hard consistency, it was very difficult to extract them whole. With the tortoises we found also the remains of

birds which varied from the size of a pigeon to that of a common fowl; to what species these belonged I could not make out, so I have sent them to Dr. Smith Woodward, of the British Museum of Natural History, for identification. In the remaining part, which varied in depth from one inch to about one foot (the bottom of the fissure being sloping), we found a part of the right tibia of the swan (*Cygnus Falconerii*) and more cervine remains, amongst which a good part of a shed antler, whose thickness at the base was one inch.

All the animal remains at the bottom were in a much more fragmentary state than those found further up. The only parts found in a good state of preservation were the above-mentioned antler and some cervine teeth; amongst these were found two human ones, belonging to the upper jaw.

I am not aware that in Malta human remains have been previously found associated with the above-mentioned animal remains. The discovery is thus one of great importance.

The fissure just described leads to another further down; in this, however, no animal remains were found.

Fissure 2.—The original opening to this fissure, which is not more than eight yards apart from Fissure 1, is a crevice of the slanting type, and the fissure is quite different from Fissure 1, too; in fact, it is a straight crevice in the rock, which widens as it goes down; its direction is N.W. to S.E. The present entrance, which is a section of it, faces the S.E.; its greatest height just permitted one to stand up straight. The digging here was conducted by Dr. T. Ashby, who was assisted by Captain F. H. S. Stone, of the P. & O. s.s. *Isis*. The earth in this fissure, which was of the same quality as that in Fissure 1, was mixed almost to the bottom with the white dust of the Globigerina stone of the quarry. The animal remains which I could identify belonged to the stag (*C. elaphus* var. *barbarus*), a dormouse (*Myoxus melitensis*), two species of swan (*Cygnus Falconerii*), and several species of birds which have not yet been identified; together with these were also found parts of the carapace of the tortoise which must have been not much smaller than the gigantic tortoise found at Corradino two years ago, and about which a full report by Professor N. Taghaferro was published in the Bulletin of the Malta Historical and Scientific Society. All the doubtful bones from this fissure have been also sent for identification to the British Museum.

Herba Fissure No. 2.

Prof. Zammit and Mr. Rizzo did some more digging in Fissure No. 2, which extends still further in. The earth here continued to be of the usual red quality, and in it the animal remains belong to the stag, tortoise, swan, and birds which vary from the size of a pigeon to that of a duck or small goose. No remains of the *Myoxus* were met with during this period of excavations.

Some of the bones are in a very good state of preservation; others, however, are so very friable as to make it almost impossible to extract; others are in such a fragmentary state as to leave no hopes for identification.

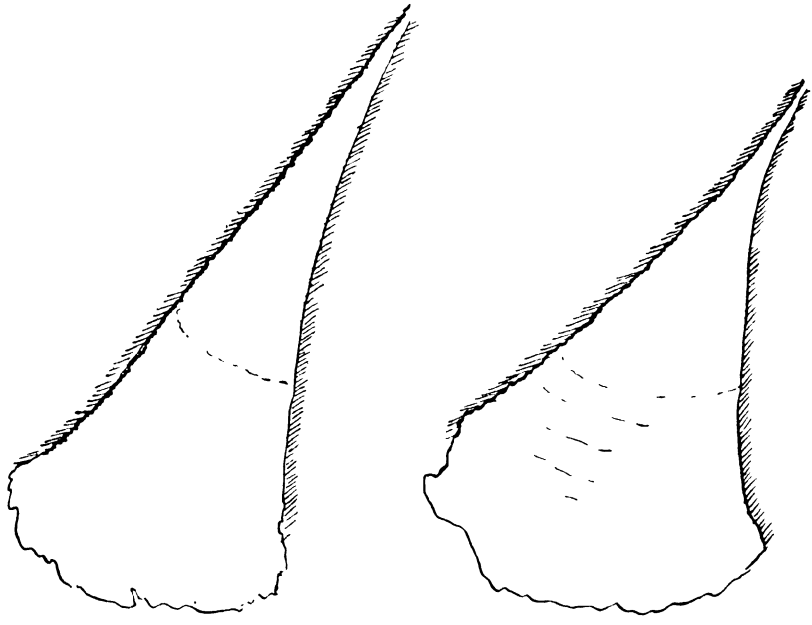
The remains of the smaller birds are identical with those sent to

Dr. Woodward to be identified. I may also state that there is yet no sign of the end of this fissure.

Herba Fissure No. 3.

This fissure, which is only a few feet apart (to the N.W.) from the spot where Fissure No. 1 stood, promises to extend much more than any of the other two, so a trench about six or seven feet deep and about four or five feet square has been cut in it. For a couple of feet from the surface the earth is of the usual red type, mingled with stones and large pieces of stalactitic formations. In this layer the remains of stag in a most fragmentary state, and those of the same small tortoise met with in Fissure 1, are found in abundance, and, though the earth here is rather loose, the bones crumble to pieces as soon as touched.

The remaining four or five feet of earth are also of the red quality, but mingled with a greyish clay which increases as it goes further down, thus giving a hard consistency, which towards the bottom increases to such a degree as to make the work rather difficult, and the



Types of Slanting Fissures.

animal remains almost impossible to extract. The bones here belong to the swan, stag, and probably a gigantic tortoise; remains of small birds are also met with.

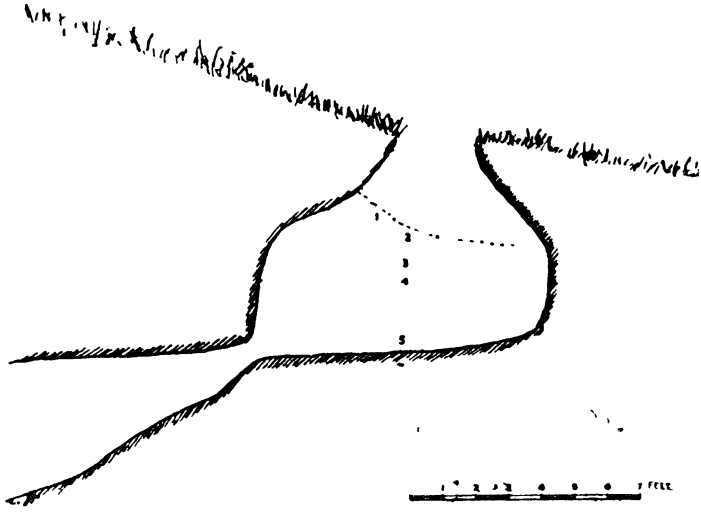
I have assisted in the digging myself and can state that the bones have been deposited in fragments, and many of them in such a bad state as to render identification quite impossible. In the last two feet of earth stalagmitic formations are also found in abundance, thus

rendering the work even more difficult; these, however, must have been carried into the fissure together with the bones. All the bones are found lying in such confusion that there is no doubt they have been carried into the fissure by some inrush of water.

The shape of the fissure cannot at present be imagined, for, as already stated, it seems to extend considerably in all directions, and what has often been thought to be the bottom of it was only some large stone which has been also introduced there.

The smaller specimens of avian remains belong to the species whose identification will also be due to the specialists of the South Kensington Museum.

Burmeghez Quarries.—These extensive quarries, known as 'Il Barrieri ta Burmeghez,' are situated at a short distance from the Herba



Section of 'Herba Fissure 1.'

1. *Sus scrofa* (pig).
2. *Cervus elaphus* var. *barbarus* (stag).
3. ditto ditto + *Tapes decussata.*
4. Tortoise and avian remains.
5. Swan, more cervian remains, and human teeth.

quarry, and can be also reached from the road which leads from the Marsa to Mkabba. Several of these quarries have been already converted into cultivated fields, but many are still worked, and in these fissures are continually met with.

The Fissures.—These, which have been also dug by Dr. T. Ashby, are all situated at a great depth from the surface (perhaps fifty feet or more), and they are all of the slanting crevices type. The animal remains found in them, and which Dr. Ashby consigned to me for examination, consist of the remains of the stag which must have been so common in those localities, and which Prof. Tagliaferro describes as a

small variety of the *Cervus elaphus* var. *barbarus*, some equine teeth, a humerus of a tortoise of the same species as those found in Herba Fissure 1, and some limb-bones of small mammals.

The Ductless Glands.—Report of the Committee, consisting of Professor Sir EDWARD 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 Secretary has been engaged upon several problems connected with internal secretion. In conjunction with Mr. Wheeler, he has investigated the effects of extirpation of the medulla of the adrenal bodies, leaving (as far as possible) the cortex undamaged. Account has also been taken, in some of these experiments, of the abdominal chromaphil body. The results obtained so far indicate that it is the cortex and not the medulla which is essential to the life of the animal. It seems likely that the adrenin function of the chromaphil tissues is only called into requisition in emergencies (as in certain emotional conditions [Cannon]).

Incidentally an inquiry into the action of hormones on the vasomotor reflexes has led to a study of certain general aspects of such reflexes. The results are published in the *Quarterly Journal of Experimental Physiology*, vol. ix.

The Secretary is reinvestigating the relation of the islets of Langerhans to the zymogenous tissues of the pancreas. No definite conclusions have yet been reached.

Some points in the structure of the pituitary have also received attention (*s.v.*, *Practitioner*, Jan. 1915, p. 16).

Mr. A. T. Cameron has continued his investigations on the distribution of iodine in plant and animal tissues. His new results confirm those previously published (*J. Biol. Chem.*, 1914, 18, 335-80). The results below are for dry tissue. He finds that iodine is an invariable constituent of ascidian tests, the amount varying from a trace up to about 0·3 per cent. The endostyle contains no detectable quantity, and therefore, as regards iodine function, appears to differ from thyroid. The other tissues contain traces, which increase with increasing amounts in the test. The outer layer of the foot of the horse-clam and of the cockle contains iodine of the order 0·2 per cent. Iodine is an invariable constituent of the tubes of annelid worms, the amount (in absence of sand and calcium carbonate) varying in different species from 0·1 to 0·7 per cent. The worms themselves contain amounts varying from 0·01 to 0·1 per cent. One species of diatom showed no detectable quantity of iodine, indicating that diatoms may not be a link in the cycle of iodine in sea-life. Some fresh thyroid material has been examined. The thyroid of the dog-fish, *Squalus sucklii*, contains approximately 0·2 per cent. iodine and the amount does not appear to vary appreciably at different seasons of the year. A case of goitre

in this species has been reported on (Cameron and Vincent, *J. Med. Res.*, May 1915), which is the first observed in salt-water fishes. The thyroid of the rat-fish (*Hydrolagus collicii*, a holocephaloid) contains quantities of iodine varying from 0·5 to 0·75 per cent. (different samples). Several species of sea-birds have been examined. The thyroids of the surf scoter (2 specimens) contain 1·1 per cent., of the pigeon guillemot 0·4 per cent., and of the marble murrelet 0·3 per cent. The thyroids of crows (*Corvus corvinus*), feeding largely on clams, contain 0·75 per cent. iodine. These are all high values. The increasing ratio, previously shown to exist between the weight of the dried thyroid and the weight of the animal, with increased development, is confirmed. For *Squalus sucklii* it is about 6 mg. per kg., for *Hydrolagus collicii* about 12 mg. per kg., and for the birds examined the average figure is 25 mg. per kg.

The Committee ask to be reappointed with a grant of 35*l*.

Electromotive Phenomena in Plants.—Report of the Committee, consisting of Dr. A. D. WALLER (*Chairman*), Mrs. WALLER (*Secretary*), Professors J. B. FARMER, T. JOHNSON, *and* VELEY, *and* Dr. F. O'B. ELLISON.

The Electrical Measurement of the Vitality of Vegetable Tissues. Plumule v. Radicle.

By A. D. WALLER, *M.D., F.R.S., and* A. M. WALLER.

IN pursuance of experiments described in a previous Report to the Association (Birmingham, 1913, p. 241) we have endeavoured to estimate the relative vitality of the stems and roots of seedlings by measuring the voltage of the blaze-currents excited by single induction shocks.[1] We took for this purpose the seedlings of barley—*Hordeum vulgare*—applying the test to the separated plumule and radicle respectively on the fourth and on the sixth day of germination on moist blotting-paper at a temperature of 18° to 20°C. As in previous experiments, we used two galvanometers in circuit in order to read upon one or other of their two scales values of first responses, whether these happened to be of low or high voltage, but we give our results reduced to one of the two scales, that, namely, in which 0·01 volt through 1·10⁶ ohms give a deflection of 12 degrees. The distance between the unpolarisable electrodes upon which the plant is laid was kept as nearly as possible constant as 5 mm. The galvanometer connections (see fig. 1) were taken such that the injury-current in the plant from the cut end B to the tip A was positive, so that the first response to an induction shock in the same or in the opposite direction was directed from A to B (in the plant), *i.e.*, in the negative direction. [We observe

[1] The Report in question is itself a continuation of work first described in 1900. Waller, 'An Attempt to Estimate the Vitality of Seeds by an Electrical Method,' *Proc. Roy. Soc.*, vol. 68, p. 79, 1901. Also Waller, 'Signs of Life from their Electrical Aspect,' John Murray, London, 1903.

the convention of reading deflections from left to right as ' positive,' from right to left as ' negative.']

The plant was excited by a single-break induction shock first in the positive then in the negative direction, weak then strong, from a Berne induction coil with two Leclanché cells (=2·9 volts) in the primary circuit; for ' weak ' and ' strong ' shocks the secondary coil was set at 1,000 and 10,000 units of the scale. As will be seen from the protocols of experiment, the results of individual trials vary considerably in magnitude, a weak shock to one plant may produce a larger effect than that produced on another plant by a strong shock, and as a rule the effect of a second strong shock is considerably smaller than that of a previous strong shock. We have, therefore, taken average results of first trials, and have not taken into comparison the results of second

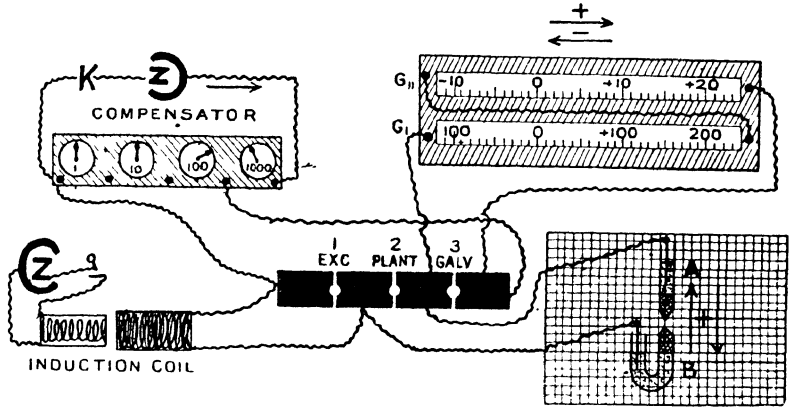


FIG 1.— DIAGRAM OF CIRCUIT FOR TESTING SEEDS.

trials, especially when strong excitation has been employed. Such average values show clearly enough that the effects of strong excitation exceed those of weak excitation, and, as regards the particular question we set ourselves to answer by these experiments, the electrical response of a plumule (*Hordeum vulgare* is so far the only seedling we have examined) is of considerable higher voltage than that of a radicle —*e.g.*, the former is considerably above 0·01 volt, the latter considerably below.

In consequence of excitation the electrical resistance of the plant is diminished; the diminution is attributable to the chemical dissociation which has given rise to the blaze-current; it is greater after strong than after weak excitation, and the increased conductivity appears to be in relation with the magnitude of the previous blaze-current. Thus we find for a plumule a diminution of resistance of 30 per cent. after a blaze-current of 0·04 volt, and for a radicle a diminution of less than 10 per cent. after a blaze-current of below 0·01 volt. But the point requires further investigation; we have not yet found means to distinguish the possible effect of water-transport from that of dissociation

in the increase of conductivity caused by electrical excitation. The value of such increase is expressed in the last column of the protocols as the numerical ratio between the deflections by 0·01 volt before and after excitation. Thus, *e.g.*, in Observation IV., the deflections as given in columns 2 and 12 are 60 and 80 respectively, and the increase of conductivity is therefore expressed by the fraction $\frac{80}{60}$ or 1·33.

We give below the detailed protocols of typical observations, each consisting of ten tests, and a summary of other observations, each of which also comprised ten tests.

Column 1 gives the E.M.F. of the accidental current or current of injury of the plant, measured by compensation. The prefixed sign + signifies that its direction in the plant is from B to A. In Observation II. its high value is due to the fact that B is a transverse section, *i.e.*, the seat of known injury. The magnitude of such injury-current is in itself to some extent an indication of the degree of vitality. The blaze-currents (columns 5, 7, 9, and 11) are of opposite direction to the injury-current.

Column 2 gives in scale degrees the observed magnitude of the galvanometric deflection by 0·01 volt. Comparison of this deflection with the deflection by 0·01 volt through 1,000,000 ohms indicates the resistance in circuit.

Columns 3 and 13 give in ohms × 1,000 the resistance in circuit before and after excitation.

Columns 4 and 6 give in scale degrees the observed magnitudes of the blaze deflections in response to weak-break induction shocks in the + and − directions.

Columns 5 and 7 give the calculated values of the E.M.F. indicated by the observed deflections of columns 4 and 6.

Columns 8 and 10 give in scale degrees the observed magnitudes of the blaze deflections in response to strong-break induction shocks in the + and − directions.

Columns 9 and 11 give the calculated values of the E.M.F. indicated by the observed deflections of columns 8 and 10.

Column 14 gives the relation of the conductivity after excitation to that before excitation taken = 100. Thus the number 133 signifies that the conductivity has been increased 33 per 100.

OBSERVATION I.—Rootlets of *Hordeum vulgare*. 4th day of germination.

	I. Inj. Curr.	II. $\frac{1}{100}$	III. ∴ R × 1,000	IV. 1,000 + ⟶	V. ∴ volt.	VI. 1,000 − ⟵	VII. ∴ volt.	VIII. 10,000 + ⟶	IX. ∴ volt.	X. 10,000 − ⟵	XI. ∴ volt.	XII. $\frac{1}{100}$	XIII. ∴ R
G_1		—						—		—			
G_2	—	25	480	−12	−0·0048	−22	−0·0088	−15	−0.0060	−60	−0·0240	30	400
	—	— 20	600	−12	−0·0060	−45	−0·0225	— 0	0	— −5	−0·0025	23	522
	—	— 35	343	nil	0	− 7	−0·0020	— +30	−0·0086	— −15	−0·0043	40	300
	—	72	167	nil	0	0	0	— +30	+0·0042	— −7	−0·0010	72	167
	—	70	171	+5	+0·0007	−30	−0·0043	— +35	+0·0050	— −10	−0·0014	70	171
	—	23	522	+5	+0·0022	−35	−0·0152	— +38	+0·0165	— −20	−0·0087	25	480
	—	18	667	−15	−0·0083	−12	−0·0067	— −15	−0·0083	— −36	−0·0200	20	600
	—	25	480	−3	−0·0012	−30	−0·0120	— +25	+0·0100	— −30	−0·0120	25	480
	—	30	400	nil	0	−11	−0·0037	— +3	+0·0010	— −30	−0·0100	30	400
	—	25	480	−35	−0·0140	−20	−0·0080	— −35	−0·0140	— −35	−0·0140	25	480
			430	Average	0·0037		0·0083		0·0074		0·0098		400

OBSERVATION II.—*Hordeum vulgare.* Plumule cut on 7th day of germination. Distance between electrodes = 5 mm.
Galvanometer deflection by 0·01 volt through 10^6 ohms = 10 divisions.

			'Weak' (1,000)				'Strong' (10,000)					
1 In. C.	2 $\frac{1}{100}$	3 ∴ R × 1,000	4 Exc + ⟶	5 ∴ V.	6 Exc. − ⟵	7 ∴ V.	8 Exc + ⟶	9 ∴ V.	10 Exc − ⟵	11 ∴ V.	12 $\frac{1}{100}$	13 ∴ R × 1,000
+0·060	25	400	−100	−0·040	−60	−0·024	−175	−0·070	−20	−0·008	35	286
+0·040	60	166	−180	−0·030	−120	−0·020	−150	−0·025	−20	−0·003	75	133
+0·030	50	200	−200	−0·040	−50	−0·010	−200	−0·040	−10	−0·002	75	133
+0·043	35	286	−175	−0·050	−140	−0·040	−175	−0·050	−25	−0·007	50	200
+0·043	35	286	−175	−0·050	−105	−0·030	−175	−0·050	−25	−0·007	50	200
+0·027	50	200	−125	−0·025	−100	−0·020	−150	−0·030	−25	−0·005	60	166
+0·041	15	666	−45	−0·030	−30	−0·020	−60	−0·040	−15	−0·010	25	400
+0·030	30	333	−90	−0·030	−15	−0·005	−180	−0·060	−60	−0·020	40	250
+0·022	10	1,000	−50	−0·050	−30	−0·030	−60	−0·060	−10	−0·010	15	666
+0·020	20	500	−80	−0·040	−20	−0·010	−100	−0·050	−10	−0·005	25	400
	Average =		—	−0·0380	—	−0·0210	—	−0·0470	—	−0·0080		

OBSERVATION III.—Rootlets of *Hordeum vulgare*. 6th day of germination.

			'Weak.'				'Strong'						
1 In. C.	2 $\frac{1}{100}$	3 ∴ R ×1,000	4 Exc + ⟶	5 ∴ V.	6 Exc − ⟵	7 ∴ V.	8 Exc.+ ⟶	9 ∴ V.	10 Exc.− ⟵	11 ∴ V	12 $\frac{1}{1000}$	13 ∴ R ×1,000	14 Cond. (100)
+0·0200	30	400	−12	−0·0040	−18	−0·0060	−28	−0·0093	−50	−0·0167	30	400	100
+0·0100	40	300	−8	−0·0020	−10	−0·0025	−10	−0·0025	−25	−0·0063	42	285	105
+0·0140	30	400	+7	−0·0023	+2	+0·0006	+45	+0·0150	−34	−0·0113	30	400	100
+0·0270	35	343	−2	−0·0005	−10	−0·0028	−30	−0·0085	−50	−0·0167	35	343	100
+0·0200	25	480	−5	−0·0020	−15	−0·0060	+25	+0·0100	−60	−0·0240	25	480	100
+0·0270	20	600	−18	−0·0090	−30	−0·0150	+20	+0·0100	−30	−0·0150	25	480	125
+0·0050	50	240	−10	−0·0020	−16	−0·0032	+15	+0·0030	−42	−0·0084	55	218	110
+0·0040	40	300	+12	+0·0030	−20	−0·0050	+20	+0·0050	−25	−0·0062	45	267	112
+0·0030	50	240	+5	+0·0010	−12	−0·0024	+12	+0·0024	−11	−0·0022	55	218	110
+0·0250	30	400	−12	−0·0040	−28	−0·0093	−10	−0·0033	−40	−0·0133	34	347	113
Average 0·0172	—	370	—	0·0030	—	0·0051	—	0·0069	—	0·0120	—	344	108

OBSERVATION IV.—Plumules of *Hordeum vulgare*. 6th day of germination.

1 In. C.	2 $\frac{1}{100}$	3 ∴ R × 1,000	4 Weak Exc + ⟶	5 ∴ V.	6 Weak Exc. − ⟵	7 ∴ V.	8 Strong Exc + ⟶	9 ∴ V.	10 Strong Exc − ⟵	11 ∴ V	12 $\frac{1}{100}$	13 ∴ R × 1,000	14 Cond. (100)
+0·05	60	200	−12	−0·0020	−20	−0·0033	−200	−0·0333	+14	+0·0023	80	150	133
+0·03	30	400	−6	−0·0020	−6	−0·0020	−36	−0·0120	+50	+0·0167	40	300	133
+0·03	24	500	−14	−0·0058	−12	−0·0050	−72	−0·0300	+32	+0·0133	40	300	167
+0·06	36	333	−90	−0·0250	−24	−0·0067	−200	−0·0555	−100	−0·0278	50	240	139
+0·04	24	500	−40	−0·0167	−80	−0·0333	−200	−0·0833	+20	−0·0083	30	400	125
+0·04	30	400	−30	−0·0100	−100	−0·0333	−120	−0·0400	−30	−0·0100	40	300	133
+0·04	30	400	−6	−0·0020	−20	−0·0067	−160	−0·0533	−120	−0·0400	40	300	133
+0·10	28	428	−90	−0·0321	−70	−0·0250	−200	−0·0714	+100	+0·0357	45	267	161
+0·05	30	400	−40	−0·0133	−8	−0·0027	−100	−0·0333	−34	−0·0113	40	300	133
+0·06	30	400	−150	−0·0500	−50	−0·0167	−200	−0·0667	+10	+0·0033	40	300	133
+0·05	—	396	—	0·0159	—	0·0135	—	0·0479	—	0·0169	—	286	—

Hordeum vulgare.—Summary.

	R × 1,000	Weak Exc.	Strong Exc.	R × 1,000	Cond. (100)
I. Radicle 4 days	430	0·0037	0·0074	400	107·5
II. Plumule 6 days	404	0·0380	0·0470	283	139
III. Radicle 6 days	370	0·0030	0·0069	344	107·5
IV. Plumule 6 days	396	0·0159	0·0479	286	138

Alterations of temperature give rise to considerable alterations of magnitude of blaze-currents and of electrical conductivity; it is not permissible, *e.g.*, to compare effects observed at 15° and 25°; the observations reported above were taken within the range of 18° to 20°.

Influence of Temperature.—During the years 1898-1900, when one of us was occupied with the examination of the physiological character of the blaze-current and of the physical conditions by which it is modified, systematic observations and records were taken of the influence of temperature which at that time were not written up, and from which a representative experiment is now given in order to show the range of the temperature modification.

Time.	Temp.	Cond.	Bl. C. Corrected for Cond.
0 min.	18°	1·0	0·0163 volt.
3 ,,	18	1·0	0·0138 ,,
6 ,,	18	1·0	0·0130 ,,
9 ,,	22	1·3	0·0193 ,,
12 ,,	27	1 8	0·0192 ,,
15 ,,	33	2·1	0·0095 ,,
18 ,,	37	2 6	0·0023 ,,
21 ,,	40	3 0	0·0016 ,,
24 ,,	42	3 0	0 ,,
27 ,,	44	3·0	0 ,,
30 ,,	40	2·8	0·0005 ,,
33 ,,	36	2·4	0·0048 ,,
36 ,,	32	2·0	0·0062 ,,

Our work during the last year, 1915, has been directed towards determining whether Waller's blaze-currents can be used as a practical test of the germination value of seeds.

Our experiments have been carried on in collaboration with Mr. D. Finlayson, who sends us samples from his Seed-Testing Laboratories, Wood Green, London, N. Our reports on seeds tested by Dr. Waller's electrical method have corresponded exactly with Mr. Finlayson's reports by his seed-germination method.

The seeds must be soaked a certain number of hours before they ripen sufficiently to give off their full blaze-current; dried peas require at least twelve hours' soaking.

An average blaze-current of ·03 or ·04 volt indicates a high-class pea

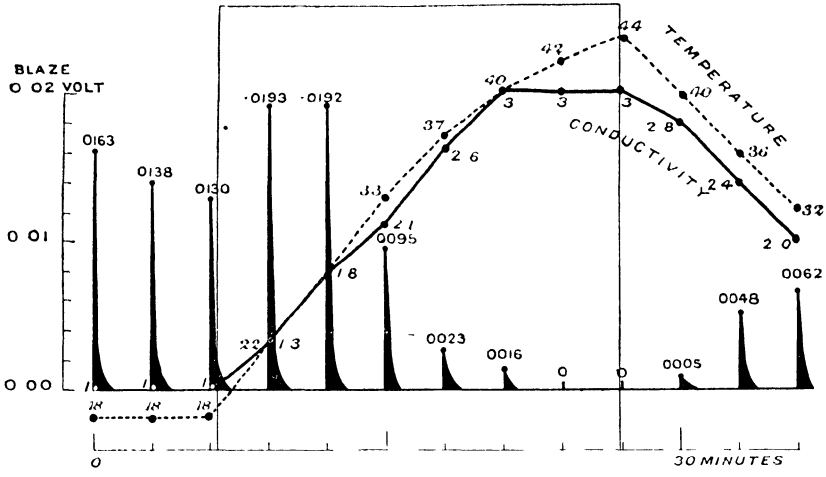


FIG. 2.

of which 97 per cent. would germinate; individual peas out of the series tested would give ·07 or ·09 volt; others only 01 or 02 volt.

The electrical test is much quicker than the germination test. If we find we can work rapidly enough, the method may be of use to the seed merchant who needs to know as quickly as possible the value of seeds in the market.

We are still engaged in making a long series of tests on different varieties of seeds.

The Structure and Function of the Mammalian Heart.—Report of the Committee, consisting of Professor C. S. SHERRINGTON *(Chairman)*, Professor STANLEY KENT *(Secretary)*, *and* Dr. FLORENCE BUCHANAN, *appointed to make further Researches thereon. (Drawn up by the Secretary.)*

THE original Committee consisted of Professor Francis Gotch, Chairman, and Professor Stanley Kent, Secretary. This Committee was deprived of its Chairman by the death of Professor Gotch. Professor Sherrington was appointed to take his place. Dr. Florence Buchanan was added to the Committee at the annual meeting of the Association in 1914.

The following Report consists of two parts. The first part deals with the work of the Committee for the year 1913-14. This was delayed last year owing to the fact that the Association met in Australia.

The second part deals with the work of the Committee for the year 1914-15.

Part I.

The work of the Committee since the date of the last Report[1] has been concerned (*a*) with investigations undertaken in order to confirm the existence of conducting paths between the auricle and ventricle other than the auriculo-ventricular bundle, and (*b*) with an examination of the functions of such paths.

With regard to the former, viz. the existence of conducting paths between the auricle and the ventricle other than the auriculo-ventricular bundle, it has been established that there exists on the right side of the heart a bundle of muscular tissue which forms a path of conduction between the auricle and ventricle, and which is capable of conducting impulses between these chambers in the absence of the auriculo-ventricular bundle. The evidence upon which this assertion is based is partly histological and partly experimental. By histological examination it has been possible to establish the following facts. Serial sections cut through the auriculo-ventricular junction at a certain point show ventricular muscle fibres approaching the junction from three directions. These fibres are connected with fibres of auricular origin through a mass of modified tissue presenting characters similar to those seen in the sino-auricular and auriculo-ventricular nodes.

The mass of modified tissue is well defined. It is usually of olive shape, and consists of a central mass in which the modification is well marked, with a peripheral portion which more nearly approaches normal muscle in structure. With the peripheral portion on one side the ventricular muscle is connected, whilst auricular muscle is connected with the peripheral portion on the opposite side.

On account of the character of the tissue and its resemblance to nodal tissue in other parts of the heart, it is called a 'node.' From its position it is called for purposes of identification the 'right lateral node.' This structure is so placed that impulses passing down the auricular wall would traverse the node before reaching the ventricle. If, as suggested many years ago,[2] impulses are conducted at a slower rate over the modified tissue of the heart than over ordinary cardiac muscle, there may be here, as in the case of the auriculo-ventricular bundle, an explanation of the pause which occurs between the auricular and the ventricular beat. It may be pointed out too that the sectional area of the path is at one point extremely small, and there is evidence in the work of Romanes, Gaskell, and others to prove that in such circumstances the rate of transmission is slow. The pause may, therefore, be regarded as being due partly to transmission through modified tissue, and partly to transmission along a muscular path of narrow cross-section.

The experimental evidence of the existence of a path of conduction between the auricle and ventricle in this situation is of the following kind. It has been stated by many that auricular contractions fail to

[1] *Annual Report*, 1913, p. 258.

[2] *Journal of Physiology*, xiv. No. 1, and xiv. Nos. 4 and 5.

pass over the auriculo-ventricular groove to the ventricle as soon as a physiological section has been made through the septal connection (auriculo-ventricular bundle). I have found it to be the case, however, that the pulsations continue to be transmitted to the ventricle, in spite of the severance both of the septal connection and of the greater portion of the outer walls of the chambers, in those cases where the part remaining unsevered includes the particular tract of the heart already referred to as showing histologically the presence of the right lateral connection. Indeed, it has been possible to reduce this tract to very narrow limits, and I have found the following experiment to be uniformly successful, provided the part remaining is situated at the exact spot described.

An animal having been anæsthetised and the thorax opened, a thin sharp pointed knife is passed through the heart at the level of the auriculo-ventricular junction, about half an inch from the right side, the edge of the knife being towards the left. The knife is at once carried across the heart towards the left, severing in its course the major part of the junctional tissues between the right auricle and the right ventricle, the septal connections, including the auriculo-ventricular bundle, and the whole of the connections between the left auricle and the left ventricle. In such circumstances the heart still continues to beat, and the two sets of chambers, the auricles and ventricles, maintain their co-ordination.

By careful dissection it is possible to reduce the width of the bridge of tissue connecting the auricles and ventricles until it is no more than a couple of millimètres across, without in any way interfering with the co-ordinated action of the two sets of chambers.

Sections made subsequently have shown that muscular fibres are present throughout the entire length of this bridge, and that they form a continuous tract of conducting tissue, connected above with the auricle and below with the ventricle.

Any considerable narrowing of the bridge beyond this point—or a complete rupture of it—results in a cessation of the co-ordinated action, and a like result is obtained unless the situation of the bridge is very carefully selected. If, after a narrowing of the bridge to about two millimètres, the heart is allowed to remain until the automatic beats originating in the auricle cease and all the chambers are quiescent, it is still possible to excite beats artificially in either auricle or ventricle by appropriate stimuli, and it is found under these conditions that contractions excited in the auricle pass through to the ventricle, whilst beats excited artificially in the ventricle pass through to the auricle and give rise to auricular contractions.

The conclusions which may be drawn from the facts stated appear to be as follows:—The widely accepted statement that the auriculo-ventricular bundle constitutes the only path of conduction between the auricle and ventricle can no longer be upheld. Both histological and experimental evidence go to prove that an alternative path exists in the situation described.

This alternative path can function and can preserve co-ordination between the auricles and ventricles after the septal connections (auri-

culo-ventricular bundle) and the whole of the rest of the tissues connecting the auricles to the ventricles have been severed.

Impulses are capable of passing over the newly described path either in the normal direction (auricle to ventricle), or in the reverse direction (ventricle to auricle). The connection of auricle to ventricle being through the tissue of the right lateral node, which presumably conducts impulses at a slower rate than ordinary cardiac tissue, the pause may reasonably be explained as being due to this circumstance. The presence of such an alternative path has to be reckoned with in putting forward possible explanations of various anomalies of cardiac action.

References.

[1] Observations on the Auriculo-ventricular Junction in the Mammalian Heart,' *Quart. Jour. Experimental Physiology*, vii. 2. 193.

[2] The Structure of the Cardiac Tissues at the Auriculo-ventricular Junction,' *Proc. Phys. Soc.* Nov. 1913. *Jour. Phys.* xlvii. 4 and 5.

[3] Sur le Système excitateur et conducteur du Cœur,' *Arch. des Maladies du Cœur.* Paris. Jan. 1914.

[4] The Right Lateral Auriculo-ventricular Junction of the Heart,' *Proc. Phys. Soc.* March 1914. *Jour. Phys.* xlviii. 2 and 3.

[5] Some Problems in Cardiac Physiology,' *B.M.J.* July 18, 1914.

[6] Illustrations of the Right Lateral Auriculo-ventricular Junction in the Heart,' *Proc. Phys. Soc.* June 1914. *Jour. Phys.* xlviii. 5.

[7] A Conducting Path between the Right Auricle and the External Wall of the Right Ventricle in the Heart of the Mammal,' *Proc. Phys. Soc.* June 1914. *Jour. Phys.* xlviii. 5.

PART II.

During the past year attention has been directed principally to the working out of detail, and a considerable amount of material is practically ready for publication. The most important new fact put on record is perhaps that of the existence of considerable masses of muscle in the auriculo-ventricular valves. This will necessitate a review of the usual conception of the action of these structures.

References.

[8] On the Mechanism of the Cardiac Valves,' *Proc. Royal Soc.* B. vol. 88, 1915.

[9] Illustrations of Muscular Tissue in the Auriculo-ventricular Valves of the Mammal's Heart,' *Proc. Phys Soc.* July 3, 1915.

The Committee ask to be reappointed, with a grant of 50*l*.

The Renting of Cinchona Botanic Station in Jamaica.—Report of Committee, consisting of Professor F. O. BOWER (*Chairman*), Professor R. H. YAPP (*Secretary*), *and* Professors R. BULLER, F. W. OLIVER, *and* F. E. WEISS.

THE Committee for 'The Renting of Cinchona Botanic Station in Jamaica' report that since the last meeting of the British Association

the agreement with the Jamaican Government has been signed, providing for the annual tenancy of the station, at a rent payable to the Jamaican Government of 25*l.* per annum, the tenancy to date from October 1, 1914. The grant of 25*l.* has been drawn from the Treasurer of the Association, and has been paid as the first year's rent.

Owing to the state of war, no application has been received for the use of the station by any British subject. But an application for its use having been made from Mr. J. Arthur Harris and Mr. Lawrence, of the staff of the Cold Spring Harbour Station for Experimental Evolution, and Mr. William Harris, F.L.S., Superintendent of the Jamaica Gardens, having supported it, the Committee agreed to grant the application. One reason for this was that during the tenure of the Cinchona Station by the New York Botanic Garden, Professor Bower and Mr. Drummond had both been hospitably given the use of the station.

In view of the fact that the war has extended over the first year of tenancy for which the full rent has been paid, and that consequently no British applicant for use of the station had appeared, the Jamaican Government were asked if they could see their way to taking this into account in favour of the Committee. Further, the stringency of money during war may make a renewal of the grant by the British Association a matter of difficulty—or, at least, of the full amount of the grant. The Jamaican Government were invited to say what they might be willing to do in the circumstances. The Colonial Secretary has replied in the following terms:—

Colonial Secretary's Office,
Jamaica, June 22, 1915.

In case of reply please quote the date of this letter and the following Nos.: 7999, 7552.

SIR,—In continuation of the letter from this Office, No. 7087/7552, dated the 1st instant, I am directed to inform you that the Governor has given consideration to the suggestion in your letter of May 2 on the matter of the remission of part of the rent for Cinchona Station, and that he would be glad to meet your wishes as far as possible.

2. His Excellency is informed by the Director of Agriculture that certain Botanists of the United States of America have sought to secure the use of the station. It may be possible to make the place available to them for the period in which it is not required by the British Association. If, therefore, a particular time could be stated when your Association will not require the place it would facilitate consideration of the matter of adjusting the payment of rent to suit all concerned.

3. I am to add that as your Association will not make use of the station during the current year His Excellency is disposed to remit a moiety of one year's rent, but before passing definite orders on the point would be glad to hear from you on the subject of the preceding paragraph.

I have the honour to be, Sir,
Your obedient servant,
(Signed) R. W. JOHNSTONE,
Ag. Colonial Secretary.

Professor F. O. Bower,
Department of Botany, University of Glasgow,
1 St. John's Terrace, Hillhead, Glasgow.

The Committee gratefully acknowledge the generosity of the Jamaican Government in thus proposing to remit the moiety of one

year's rent. They think that the terms of the letter of the Colonial Secretary of June 22, 1915, should be accepted. They therefore ask that they be reappointed for the coming year, and that a grant of 12*l.* 10*s.* be made to cover the rent at the reduced rate. They also report that an application for the use of the station by a British botanist for the summer of 1916 is in view, but naturally, as the applicant is of military age, it must be contingent upon the state of war.

Sections of Australian Fossil Plants.—Report of the Committee, consisting of Professor W. H. LANG *(Chairman)*, Professor T. G. B. OSBORN *(Secretary)*, Professor T. W. E. DAVID, *and* Professor A. C. SEWARD, *appointed to cut Sections of Australian Fossil Plants, with special reference to a specimen of* Zygopteris *from Simpson's Station, Barraba, New South Wales.*

THE Committee report that after some delay occasioned by the disturbance of communication between Australia and the United Kingdom the specimen was sent to England for cutting. Extensive series of sections have been prepared involving a portion of the block, and have shown the specimen to be of unique interest. A preliminary account of its structure is presented by Mrs. Osborn to this meeting. The Committee ask for reappointment for another year without further grant, but with permission to carry forward the unexpended balance to allow the work to be completed.

The Influence of varying Percentages of Oxygen and of various Atmospheric Pressures upon Geotropic and Heliotropic Irritability and Curvature.—Report of the Committee, consisting of Professor F. O. BOWER *(Chairman)*, Professor A. J. EWART *(Secretary)*, *and* Professor F. F. BLACKMAN, *appointed to carry out a Research thereon.*

THE grant allocated at the meeting in Australia was drawn locally, and an account of its expenditure, and of the progress of the work, is contained in the following letter from Professor Ewart:

The University of Melbourne.

June 14, 1915.

DEAR PROF. BOWER,—I enclose herewith statement of expenditure from British Association Research Grant, practically the whole of which has been expended. It took so long, however, to obtain all the apparatus required, that most of the work done has been of a preliminary nature, such as determining the range of variation with different material, and material in various stages of development, the distinction between direct and indirect effects of altered pressure, the maximum pressures to arrest growth, and the minimum pressure to accelerate it. We have a basis to determine the influence of altered pressure

on geotropic perception and response, and seem likely in time to obtain fruitful results. The work is slow because many precautions are necessary for safety and accuracy, and only one observation can be made at a time.

We have now all the large apparatus needed, and as I have nearly 2*l.* in hand, this will cover any minor expenses needed to complete the work, such as chemicals, repairs to valves, &c.

With kind regards, I am,

Very faithfully yours,

ALFRED J. EWART.

Pending the completion of the work, the Committee ask that they be reappointed, but do not apply for any further grant.

Australian Cycadaceæ.—Report of the Committee, consisting of Professor A. A. LAWSON (*Chairman*), Professor T. G. B. OSBORN (*Secretary*), *and* Professor A. C. SEWARD, *appointed for the Collection and Investigation of Material of Australian Cycadaceæ, especially Bowenia from Queensland and Macrozamia from West Australia.*

THE Committee beg to report that progress is being made with the work, which, however, is impeded by the distances involved. It is requested that the Committee be reappointed for another year without additional grant, but with permission to carry over the unexpended balance.

The Vegetation of Ditcham Park, Hampshire.—Report of the Committee, consisting of Mr. A. G. TANSLEY (*Chairman*), Mr. R. S. ADAMSON (*Secretary*), Dr. C. E. MOSS, *and* Professor R. H. YAPP, *appointed for the Investigation thereof.*

FIELD work was carried on during the summer of 1914. The various lines of inquiry mentioned in the last report were continued: experiments were performed with evaporimeters and wet and dry bulb thermometers, the soil studies were continued, and soil temperatures investigated further.

Special studies were made on the following points:—

(1) Chalk grasslands.—A somewhat detailed analysis was made of selected areas of chalk grassland on various parts of the estate. Parts of the surrounding country were also studied for comparison. Several quadrats were laid down and charted. Special attention was paid to the relationships of the subterranean parts of the plants, both to one another and to varying depths of soil.

(2) Coppices on clay soil.—These received special attention, and a detailed floristic analysis was made of the various types. Quadrats have been charted for the detailed study of the coppice successional changes. The distribution of *Mercurialis perennis* and of *Pteridium aquilinum* is being worked out in detail.

(3) Light relations.—These have been specially studied so far in the beech-woods. A first series of experiments has been carried out during the season, which give interesting and striking results.

The enclosed areas have been charted in detail, and also photographic records have been taken from marked positions.

During the present season (1915) it has not been found possible to carry out field experiments.

The Committee ask to be reappointed, without a grant.

Experimental Studies in the Physiology of Heredity.—Report of the Committee, consisting of Professor F. F. BLACKMAN (*Chairman*), Mr. R. P. GREGORY (*Secretary*), Professor W. BATESON, *and* Professor F. KEEBLE.

EXPERIMENTAL work has been satisfactorily carried on during the past year, and a summary of the results is given below. It is hoped that it will be found possible to renew the grant, and thereby enable the results to be carried further.

SUMMARY.

Experiments by R. P. GREGORY *and* H. B. KILLBY.

The investigations into the genetics and cytology of the tetraploid races of *Primula sinensis* have been continued, and considerable progress has been made in the recognition and testing of the three different heterozygous types, AAAa, AAaa, and Aaaa. In cases where a single dose of the factor is sufficient for the perfect development of the character, these types can only be identified by the study of their progeny; in self-fertilisation, the type AAAa gives no recessives among its immediate progeny, but some of its offspring give recessives *in the next generation*; the type AAaa gives the ratio 15D:1R; while the type Aaaa gives the familiar ratio 3:1. All these types have now been identified experimentally. In the case of other factors the dominance is not complete, and among these cases there are some, notably in factors determining the shape of the leaf, the form of the corolla, and certain colour-characters, in which the tetraploid races produce heterozygous types unlike any types in the diploid races. The factorial constitution of these peculiar types is being studied, and very satisfactory progress has been made, especially in unravelling the complex of factors which, between them, determine the coloration of the flower.

It was hoped that a report on this part of the work would have been ready for publication this summer, but circumstances connected with the war have rendered delay unavoidable.

The phenomena of coupling and repulsion have been studied further, both in the diploid and in the tetraploid races. This work promises most interesting results, but has not yet progressed far enough to permit of any definite statement as to new ground gained.

Experiments by H. B. KILLBY.

The experiments on Beans (*Phaseolus*) and Marrows, begun three years ago, have been carried further. Interesting points have arisen in both cases, but further work is necessary for their elucidation.

Experiments by A. E. GAIRDNER.

Work on Wallflowers and on Tropæolum has been continued; the work on the Wallflower is approaching completion.

Experiments by E. R. SAUNDERS.

Further work has been carried out during the year on Foxgloves and Stocks. In the case of Foxgloves progress is necessarily slow, as two years are required for each generation. The further work has given indication that in respect of one of the characters investigated the species is eversporting, but a fuller analysis of the behaviour of individuals is necessary before a full statement can be made. Incidentally it has been found in the course of cross-fertilisation of heptandrons with peloric plants that these two abnormal conditions are inherited independently.

From the results obtained with Stocks it is hoped that it may be possible to show how an eversporting type may be synthesised from a true-breeding individual. Further progress has been made in the study of the inheritance of the half-hoary character, and in the identification of types required by theory but not met with in commercial material. With regard to the occurrence of doubles, the results obtained show that the excessive percentage of doubles sometimes obtained by growers and quoted in their catalogues is probably due to unconscious selection, and that the *actual output* of doubles is not in excess of the theoretical estimate.

PUBLICATIONS DURING THE YEAR

R. P. GREGORY: 'Inheritance in certain Giant Races of *Primula sinensis*.' *Rep. Brit. Assoc. Australia, Section* K, 1914.
'On Variegation in *Primula sinensis*.' *Journal of Genetics*, Vol. 4, 1915.
'Note on Inheritance of Heterostylism in *Primula acaulis*.' *Ibid.*
E. R. SAUNDERS: 'The Double Stock, its History and Behaviour.' *Journal Royal Horticultural Society*, 1915.

School-books and Eyesight.—Further Report of the Committee, consisting of Dr. G. A. AUDEN (*Chairman*), Mr. G. F. DANIELL (*Secretary*), Mr. C. H. BOTHAMLEY, Mr. W. D. EGGAR, Professor R. A. GREGORY, Mr. N. BISHOP HARMAN, Mr. J. L. HOLLAND, Dr. W. E. SUMPNER, Mr. A. P. TROTTER, *and* Mr. W. T. H. WALSH, *appointed to inquire into the Influence of School-books upon Eyesight.*

SINCE presenting its report at Birmingham in 1913 the Committee has had correspondence with education authorities, school medical officers, teachers, publishers, and authors, and is pleased to report that

widespread efforts are being made to secure the fulfilment of the Committee's recommendations, at least so far as books for young children are concerned. The Committee hopes that further progress will be made in regard to books for boys and girls over fourteen years of age. A diminution in the power of accommodation of the eye continues during this period of life, whereas at the same age there is good educational reason for an increased extent of reading and for the use of books containing a considerable amount of information. Hence visual defects frequently become evident at about the age of sixteen. The recommendations in the Committee's typographical table issued in 1913 were based on a balanced consideration of the above facts, and it is important that the standard proposed for readers over twelve years should be insisted upon.

Investigations have been made during the last two years in order to obtain an objective measurement of the gloss of paper, and the Committee is indebted to Mr. A. P. Trotter for designing a new form of gloss-tester, and for carrying out tests with books and writing-papers used in schools.

The Committee observes:—

(1) That glossiness of paper depends mainly on specular reflection, *i.e.*, reflection as from polished metals; such reflection is apt to interfere with binocular vision. The ideal surface for books would exhibit no specular reflection; all the reflected light would be scattered or diffuse reflection, equal in all directions and independent of the direction of the incident beam. Such absence of gloss is realisable in any fine white powder, such as magnesia, but not in printing papers. No harm to eyesight is, however, likely to accrue if the specular reflection is not excessive, hence the proportion of specular to diffuse reflection affords a suitable index of the glossiness of paper.

(2) That a large proportion of school-books and writing-papers are satisfactorily free from glare at angles of incidence not exceeding 45 degrees. In most of these satisfactory books the specular reflection does not exceed the diffuse reflection when the light is incident at 45 degrees, the paper being viewed from the direction of the corresponding specularly reflected rays.

(3) That when the specular reflection exceeds 56 per cent. (the diffuse reflection being then less than 44 per cent.), there is likely to be injurious glare. The risk is greater if the book is read in artificial light.

The Committee therefore hopes that publishers will select for school-books papers from which the specular reflection at 45 degrees does not exceed the diffuse reflection. Books in which the specular reflection exceeds 56 per cent. of the total reflection (specular *plus* diffuse) must be regarded as potentially injurious to eyesight.

Writing-paper for school use should not give more than 54 per cent. specular reflection at 45 degrees, since young writers often look obliquely at the paper.

The Committee finds that coloured maps can be produced without extra expense or difficulty on paper conforming with the above rules.

In some instances the effect of using suitable paper has been spoiled by the use of glaze in the colours or inks. The glossiness of paper is greatly influenced by the extent and particular method of calendering, and it is suggested that careful control of calendering will assist in obtaining the desired hardness and the even surface required, without introducing pernicious gloss.

Mr. Trotter's description of his gloss-tester is subjoined at the request of the Committee, since the recommendations in this Report require that some standardising instrument should be available.

An Instrument for Testing the Gloss on Paper and other Materials.

The principle of the method is to illuminate a specimen of the paper or other material by light falling on it at an angle of, say, 45 degrees. The observer can examine the brightness of the specimen from a direction making an equal and opposite angle of 45 degrees. The effect of the gloss is then a maximum. He can also observe it from a direction nearly parallel with the incident light. The effect of the gloss is then a minimum. The instrument provides means for making these two brightnesses equal, and for comparing them.

The instrument consists of a box 15 inches (300 mm.) long, 8 inches (203 mm.) wide, and of about the same height. In the bottom there is an opening $3\frac{3}{8}$ inches (85 mm.) by $1\frac{3}{4}$ inches (44 mm.). The box may be laid on the page of an open book, and the part of the paper seen through the opening becomes the specimen to be tested.

A small electric lamp carrying a pointer can be moved on a slide between two mirrors A and B. The lower part of the box is divided by a thin partition. Half of the specimen is illuminated from one mirror and half from the other. Two eye-tubes are arranged at *a* and *b* for observing the specimen, the view being obtained alongside the edge of a mirror. In each eye-tube there are a pair of acute-angled prisms edge to edge, by which the view of the thin partition may be cut out of view.

Let 100 be the total brightness, d the diffused brightness, and s the specular brightness $100-d+s$. The pointer attached to the lamp moves over a scale graduated from the formula

$$x=(10-\sqrt{100-s})\mathrm{L}/2(10+\sqrt{100-s})$$

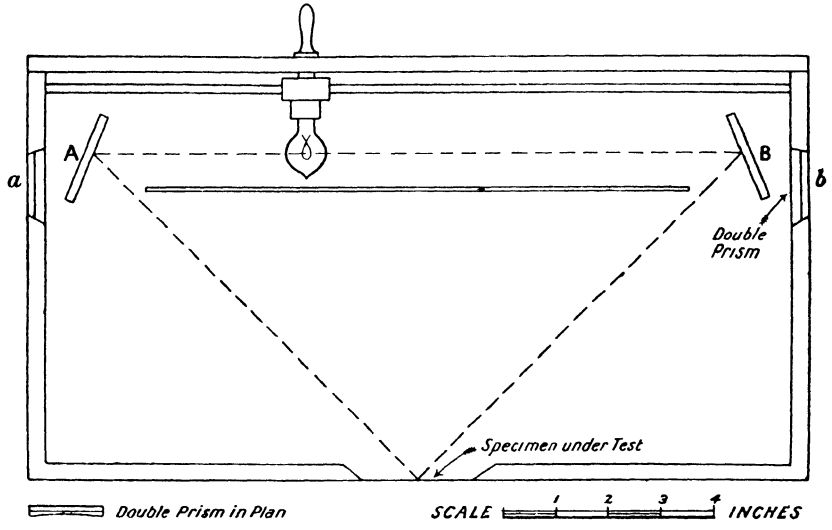
where x is a length on the scale measured from the middle point, s the specular brightness at 45° expressed as a percentage of the total brightness, and L the total length from the middle point of the opening through which the specimen is seen, to one mirror, across to the other mirror, and back to the middle point of the opening.

The whole instrument is bilaterally symmetrical, and, when the mirrors are properly adjusted, observations made from either end should give readings equidistant from the middle of the scale.

When a flattened layer of fine white powder, such as ordinary whiting, is tested, it is found practically free from gloss. In other words, the reflection is wholly diffusive, and there is no specular reflection. The brightness of the two halves is identical when the illumination is identical. The pointer is at the middle of the scale when the

specimen is viewed from either end, and indicates $s=0$, the total brightness consisting only of diffused brightness d.

If a sheet of paper is tested in this way, and is observed through eye-tube a, the brightness of the half illuminated by reflection from the mirror B will be due to the sum of the diffused brightness d and of the partial specular brightness s. The brightness of the half illuminated by reflection from the mirror A is due to diffused brightness only. The



GLOSS TESTING.

lamp must therefore be brought nearer the mirror A to make the brightness of the two halves equal. If, when a balance has been obtained, the pointer stands at 66·6, this means that the brightness viewed from a direction nearly parallel to the direction of observation consists of brightness s due to specular reflection, which is twice the brightness d due to diffused reflection, and, therefore, 66·6 per cent. of the total brightness. As a check, an observation may be made through the other eye-tube.

When the specular brightness is more than 70 per cent. of the total brightness an imperfect image of the source of light begins to be formed. A bright glistening patch appears on one half of the specimen, and it becomes difficult to match this accurately with the brightness of pure diffused reflection. For this reason the method in its present form is not applicable to materials having a pronounced gloss.

In adjusting the instrument it is laid on a mirror. The lamp is seen by reflection on one side of the partition, and when the lamp is moved it ought to appear to approach to or to recede from the eye in a straight line. The instrument should be used in a darkened room. The constancy of the candle-power of the lamp is immaterial; but it is advisable to use an evenly frosted bulb, as otherwise the asymmetry of the filament may introduce errors. The surface undergoing test should be quite flat.

A millimetre scale may be substituted for the percentage scale. The percentage of specular brightness at 45°, when the pointer is x millimetres from the middle of the scale, is then given by

$$s = 200\mathrm{L}x/(\tfrac{1}{2}\mathrm{L}+x)^2.$$

Report of the Committee, consisting of Sir HENRY MIERS (*Chairman*), Professor MARCUS HARTOG (*Secretary*), Miss LILIAN J. CLARKE, Miss B. FOXLEY, Professor H. BOMPAS SMITH, *and* Principal GRIFFITHS, *appointed to inquire into and report on the number, distribution, and respective values of Scholarships, Exhibitions, and Bursaries held by University students during their undergraduate course, and on funds private and open available for their augmentation.*

THE Committee has limited its work during the present year to the application for information to those institutions that had not sent answers to the questionary last year, and to obtaining revision of the compilation they had made from last year's answers from those who had then replied. The complete set of answers thus obtained are now to be found in Appendix I. Appendix II. is reprinted.

As the Board of Education is now engaged on a wide inquiry which covers the ground of your Committee, we have not thought it desirable to extend our inquiries further.

The information now obtained shows very clearly that the amounts allowed for scholarships can, in the immense majority of cases, be adequate for their beneficiaries to reap the full advantages of academic education only when they have friends or relations to assist them. This is most clearly shown by the reports from Oxford and Cambridge, where, thanks to the tutorial system, the authorities are in closer touch with the students than at newer institutions. A glance at the figures is enough to demonstrate this.

In Great Britain the figures are somewhat inadequate; for many of the students enjoy benefits either from the Carnegie Fund or from local scholarships of which no account is taken by the colleges. In the colleges of the National University of Ireland there is a hard-and-fast rule that the county or municipal scholarships are not tenable with full college ones. We feel that there exists a need for greater elasticity in this respect, notably in the cases of exceptional merit, where it is especially desirable that the student should gain all that is to be gained from University life.

We realise that while scholarships have one great function, that of enlarging the social area from which the supply of the learned professions is drawn, it would be well if funds were provided for private administration by the head of a college to meet the cases of brilliant students in need of further help. This might be from special funds or from the private liberality of patrons: both provisions exist at the older Universities, the patrons in the latter case being old members of the college. In our newer Universities, we venture to think that wealthy citizens, proud of their own local college, might be willing

to play the same part. We would recall the fact that the governors of Dissenting and Jewish Theological Seminaries act very generally as sponsors to the students; and urge that the heads of our provincial Universities and colleges should set forth this mode of benevolence as one worthy of emulation everywhere, that the seat of a University college would honour itself by making the best provision for the worthiest of its students.

We would recommend for general adoption the practice existing in some Colleges of inviting in advance confidential declarations from candidates that if elected they will not draw the emoluments, as a most desirable factor for enlarging the possibilities of scholarship funds.

We consider that it is undesirable to supplement scholarships by loan funds which may cripple the recipient for the best years of his life, or turn him away from academic pursuits to more remunerative occupation in order to attain liberty from pecuniary obligations. In this way the noblest aim of scholarships—to open the highest careers to the very best men, independent of lack of personal means—would evidently be hampered or defeated.

The Committee desire again to express their warmest thanks to those who by their willing answers have enabled them to collect so much valuable information.

APPENDIX I.

QUESTIONARY AND ANSWERS.

University College, Cork: March 11, 1913.

DEAR ——

On behalf of the above Committee I write to ask if you will very kindly furnish me with information in regard to the following questions:—

I. The number, duration and respective values of Scholarships, Exhibitions, and Bursaries in your College?

II. Whether two or more such benefactions are tenable together?

III. Whether any limit is imposed on the maximum annual income derived from endowments of all kinds by a single beneficiary?

IV. Have you at your disposal any funds (*a*) of permanent endowment; or (*b*) of private benefaction to supplement Scholarships, &c., for the complete maintenance of students of exceptional promise?

V. (*a*) Have cases occurred in which successful candidates have been obliged to decline Scholarships, &c., on the ground of inadequate personal means?

(*b*) Have any deserving beneficiaries retired during their course through lack of adequate means?

(*c*) Have such resignations been met by help from or through the College; and if so in what way?

VI. Will you very kindly add any further suggestions or information bearing on this matter?

I am, dear ——

Faithfully yours,

MARCUS HARTOG

(Secretary to the Committee).

ANSWERS RECEIVED.

ALL SOULS' COLLEGE, OXFORD.

I. Four Bible Clerkships, value consisting in lodging, tuition, and allowances, fully covering board during academical terms, tenable for three years.

II. No.

III. No.

IV. A sum of 150*l.* per annum in aid of non-Collegiate students in cases of need, on the recommendation of the Censor.

V. (*a*) and (*b*) No cases.

BALLIOL COLLEGE, OXFORD.

I. Annual open, 4 minor Exhibitions of 40*l.*; 3 Exhibitions of 70*l.*; 7 Scholarships of 80*l.* Annual close, 1 Exhibition of 180*l.*; 1 Scholarship of 60*l.* Every fourth year, 1 close Exhibition of 40*l.*; 1 Scottish Exhibition of 120*l.*

The above are generally tenable for the full Undergraduate course (four years). Annual; 1 Exhibition of 100*l.* for Senior Undergraduates of the College for two years.

II. No; except last Exhibition of 100*l.*, a minor Exhibition of 40*l.* is also tenable with close Scholarship of 60*l.* when the candidate has taken a high place in the Open Scholarship Examination.

III. No limit. Most scholars and some commoners hold subventions from School, County Council or City Companies, and a few gain University Scholarships.

IV. A fund of 150*l.* per annum charged on College revenues, supplemented by private benefactions, amounting to an average of 330*l.* for the last ten years. This is used to help commoners as well as scholars who need a supplement. Exceptional promise would be an additional inducement for grants, not a necessary condition.

V. (*a*) and (*b*) Not aware of such refusals for the last twenty years, but they may have occurred earlier. After the death of two predecessors it became known that they had helped privately.

(*c*) The fund under (IV.) would be applicable. Cases where a man has for family reasons to emigrate or begin earning money without completing his University career cannot of course be met.

VI. 'Given a man of health and ability sufficient to be successful in open competition, and of sufficient previous education, I believe that there is nothing to deter a poor man from a successful Oxford career. If there is any obstacle it must be found on the "lower rungs of the ladder." I am told that opportunities differ considerably in different parts of the country.'

Form sent to the father or guardian of scholars elect at Balliol College, Oxford:—

DEAR SIR, Balliol College, Oxford.

Under a system by which Scholarships and Exhibitions are filled by open competition, it will inevitably happen that they are sometimes gained by those who are not in need of the emoluments attached to them. You will have seen that this possibility is anticipated in the notice relating to Scholarships and the conditions of their tenure issued before the Scholarship Examination.

If this is the case with Mr. who has been elected to a at this College and you think it proper that he should surrender the whole or any part of the emoluments to which he is entitled while retaining the status and other privileges of a , I have to inform you that effect will be given by the College to your wishes as to the application of such emoluments. Should you express no such wishes as to the application, any money which he may surrender now, or which at any future time he may feel himself to be in a position to surrender or repay, will be paid into a Fund established in the College for the assistance of those who require assistance to avail themselves of the advantages of a University education. Any such renunciation of emoluments will be treated by the College as confidential, and those receiving the help you give will only know that it comes to them through a College Fund.

I enclose a memorandum which will inform you as to College expenses.

Will you kindly let me know what are your wishes in this matter?

I am, Sir,

Yours faithfully,

Master of Balliol College.

BRASENOSE COLLEGE, OXFORD.

I. (*a*) Open:—Scholarships of 100*l.*; number variable, about 16 of 80*l.*; unfixed number of Exhibitions of 70*l.* (*b*) Restricted:—3 Scholarships of 80*l.*; variable number of Scholarships of 70*l.*; 2 Exhibitions of 85*l.*; 3 Exhibitions of 40*l.*

II. Blank.

III. No limit.

IV. No funds specifically set aside, but men whose College emoluments are supplemented by grants from school funds, &c., can sometimes support themselves completely during their career.

V. (*a*) and (*b*) No.
(*c*) ——
VI. Scholarship Regulations contain proviso: 'The holder of any Scholarship to which no pecuniary restriction is attached will be allowed to retain the status of a scholar without receiving the emoluments, should he express a wish to that effect.'

CHRIST CHURCH, OXFORD.
I. Open: 6 Scholarships of 80*l.*; 3 Exhibitions of about 85*l.* (money and allowances). Close: 3 Scholarships of 80*l.* All tenable for two years and renewable for two more by the Governing Body, and ultimately for a fifth in satisfactory circumstances.
II. No.
III. No limit for Scholarships. Candidates for Exhibitions must satisfy the Dean that they are incapable of coming to the University without financial assistance.
IV. (*a*) Grants may be made from College Funds, not amounting in all to over 400*l.* in any one year, to scholars or commoners who need assistance. Such grants are in practice made for one year only, but are renewable.
(*b*) There is a Poor Scholars' Fund which depends almost entirely on private benefactions administered by the Dean.
V. (*a*) and (*b*) I know of none.
(*c*) Financial difficulties have been met under IV.
VI. The statutes make a similar provision to Brasenose College.

EXETER COLLEGE, OXFORD.
I. 11 Scholarships, open, of not more than 80*l.* and 1 of 100*l.*; 8 close of not less than 60*l.* and 1 or more of not more than 100*l.* (all of which may be opened in default of the preferred class of qualified candidates); 2 Scholarships of 80*l.* for persons intending to take Holy Orders and needing assistance at the University. Various Exhibitions (mostly close), all limited to those needing assistance at the University.
III. None by Statute, but by College policy.
IV. No permanent endowment; but a deserving scholar who is poor can be helped by a grant from general College Funds or a special fund.
VI. (*a*) Only Scholarships of less than 80*l.*
(*b*) None.

HERTFORD COLLEGE, OXFORD.
I. Majority Scholarships, open to Churchmen only, 30 of 100*l.* for five years; 10, varying from 40*l.* to 80*l.*, for four years, besides a number of Exhibitions.
II. Not from College sources.
III. No limit.
IV. No.
V. (*a*) Exhibitions only.

JESUS COLLEGE, OXFORD.
I. Open Scholarships, 12; close Scholarships, 19 of 80*l.* to 100*l.* Exhibitions, several open and several close, of 30*l.* to 60*l.* All granted for two years and renewable on satisfactory industry and good conduct for two more.
II. No, but a grant from the Exhibition fund may be made to a scholar or exhibitioner.
III. No statutable limit, but no grant is made out of the Exhibition Fund except to the really necessitous.
IV. (*a*) The Exhibition Fund.
V. (*a*) Only one case in forty years unable to come up on 60*l.* per annum.
(*b*) No.
(*c*) In extreme cases exceptionally large grants have been made from the Exhibition Fund.

KEBLE COLLEGE, OXFORD.
I. Scholarships of 80*l.*, Exhibitions of 50*l.* primarily for two years, though capable of being extended for two more.
II. No.
III. No.
IV. I have 200*l.* a year of permanent endowment that I can use in this way.
V. (*a*) and (*b*) No cases.

LINCOLN COLLEGE, OXFORD.

I. Scholarships, about 17 of 80*l.* or 60*l.*; Exhibitions, about 10 of 40*l.*, or more usually 30*l.*

II. No; but the value of a Scholarship may be increased, or an exhibitioner elected to a Scholarship.

III. No limit; the College is not always aware what other benefactions are held.

IV. (*a*) There is a small fund applicable.

(*b*) Occasionally private benefactions are forthcoming, or the College may grant remission of fees or other charges to deserving students.

V. (*a*) Yes, occasionally.

(*b*) and (*c*) I cannot recall such cases.

VI. A similar provision to that of Brasenose College.

MAGDALEN COLLEGE, OXFORD.

I. 30 Scholarships and Exhibitions in variable numbers, according to needs and merits of candidate: tenable for not exceeding four years as a rule, in many cases for only three, never exceeding five.

II. No; except in so far as additional grants are made from the Exhibition Fund, independently or in addition to Scholarships.

III. No limit; but we take maximum annual income into account in awarding Exhibitions or grants. There are a certain number of Scholarships and Exhibitions given by the County Councils and by the City Companies, sometimes on the results of examinations, sometimes on recommendation, which are of very material assistance to students.

IV. (*a*) The Exhibition Fund, which could in theory be used for complete maintenance of students of exceptional promise. But practically speaking, it is not so used, as we always expect that the student should enjoy some other benefaction, or that friends should come to his aid.

V. (*a*) I have known of no case.

(*b*) Very seldom.

(*c*) As a rule assistance has been given from the Exhibition Fund, supplemented by donations from private friends.

VI. It not infrequently occurs that successful candidates decline to accept Scholarships in whole or in part because they do not need the whole assistance. I am inclined to think that money given in Scholarships is at present too diffused, and that it is better for County Councils and others to concentrate their resources on a few candidates of marked ability rather than to spread them over a number of weaker candidates who often are not able greatly to profit by an University education.

MERTON COLLEGE, OXFORD.

I. 20 Scholarships of 80*l.*; 4 Exhibitions of 80*l.*, plus a limited number (about 2 a year) of 60*l.*, restricted to candidates in need of assistance at the University. All tenable at the outset for two years, renewable for two years if the holder has given satisfaction. A fifth is sometimes sanctioned for special reasons.

II. No.

III. No.

IV. An Exhibition Fund, including an annual subsidy not exceeding 400*l.* from the College, and the emoluments of vacant Scholarships and dividends from two bequests of about 60*l.* a year.

V. (*a*) No resignations. The College gives help from the Exhibition Fund to very poor students who cannot live on their Scholarships. Only lately the holder of an Exhibition of 80*l.* received an addition of 50*l.* on the grounds of poverty and exceptional promise. But so large a grant is unusual.

NEW COLLEGE, OXFORD.

I. 10 or 11 Scholarships of 80*l.* in each year, tenable for two years, renewable for two years, and in exceptional circumstances, for a fifth; 6 Scholarships are restricted in the first instance, but, if the limited candidates do not show sufficient merit, may be thrown open for that competition. About 2 or 3 Exhibitions of 50*l.*, tenable for two or three years, confined to those in need of assistance, not tenable with Scholarships.

II. Tenable with outside Exhibitions (School, County Council, &c.). We have several private Exhibitions, usually of the value of 30*l.* a year, given to those men who may be in need of assistance, tenable with a Scholarship.

IV. (*a*) The Exhibition Fund; a loan fund.
(*b*) A small private benefaction.
V. (*a*) I can scarcely remember any such case.
(*b*) I can scarcely remember any deserving candidates who have had to retire during their course for lack of means, though a man who is not succeeding well might be allowed to retire.

PEMBROKE COLLEGE, OXFORD.

I. About 30 Scholarships and 2 or more Exhibitions, tenable for four years. Most of the Scholarships are of the value of 80*l.*, 3 of 100*l.*, and about 4 of 60*l.*
II. No
III. No.
IV. There is a College Exhibition Fund expressly intended for this purpose.
V. (*a*) and (*b*) No.
VI In nearly every instance the emolument granted by the College is necessary to enable the student to come to the University.

QUEEN'S COLLEGE, OXFORD.

I. 4 open and 1 close (which in defect of qualified candidates, is thrown open). Scholarships of 80*l.* awarded annually, tenable primarily for two years, and renewable, if holders are satisfactory, for two years; for special reasons, may be continued for a fifth.

Two Bible Clerkships conferred, as vacancies occur, on deserving persons in need of assistance at the University, of 80*l.* (or 90*l.* if resident in College), on same tenure as Scholarships.

1 J. O. F Scholarship of 90*l.* every fourth year, restricted to Churchmen, and 4 J. N. F. Scholarships of 100*l.* for five years, awarded as they fall vacant, restricted to Churchmen *Cæt par.* a candidate who stands in need of pecuniary assistance is to be preferred.

Exhibitions, all close, 4 or 5 of 100*l.*; 1 of 100*l.* for two years, which may be extended to a third and to a fourth year; 1 of 42*l.*, 2 of 68*l.*; 2 of 25*l.*; 1 of 43*l.*; 1 of 6*l.*; 1 of 5*l.* 5*s.*, 1 of 9*l.* Most of these are restricted to poor and deserving students. All may be thrown open on defect of qualified candidates Close, of 70*l.* for seven years, 2, 40*l* for four years; 1, 33*l.* for four years, 2, 60*l* for four years; 1, 62*l* for students of the College in their twelfth term (theological) for one year, which may be extended to a second, 1 of 50*l* a year, and a benefaction of 10*l.*

II. No.
III. No. A large proportion of our scholars and exhibitioners receive supplementary Scholarships from their Schools or County Councils or from the City Companies. A good many are completely maintained
IV A small Exhibition Fund might very occasionally be available, but it cannot be advertised.
V (*a*) No
(*b*) No
(*c*) Difficulties have frequently been met by aid from the Exhibition Fund.

ST. JOHN'S COLLEGE, OXFORD.

I. Open Scholarships, 13 of 80*l.*; close Scholarships, 22 of 100*l.* (besides 4 open to members of the College of 4 terms standing of 80*l.*, and only tenable for one or two years). All open Scholarships and 7 of the close, tenable for four years, which may be increased to five, 15 close Scholarships, tenable for five years, variable number (2 at present) of 80*l*, restricted to undergraduates of 4 terms.

At present, 7 open Exhibitions of 40*l* to 70*l.*, tenable as open Scholarships; 5 close Exhibitions of 40*l.* to 80*l.*, tenable as open Scholarships. Variable number (5 at present) restricted to undergraduates of 4 terms, of 20*l.* to 60*l.*

II. Scholarships and Exhibitions not tenable together.
III. No limit.
IV. (*a*) The Exhibition Fund of not less than 600*l.* per annum. It is not usual to grant more than 60*l.* in one year to an individual.
(*b*) A small fund of about 40*l.* in the hands of the President, sometimes augmented by private gifts to 70*l.*, is usually distributed in gifts of about 10*l.* to deserving and needy undergraduates, not necessarily scholars or exhibitioners.

V. (*a*) I cannot recall any.

(*b*) I think not.

(*c*) If such resignations were threatened, the College would certainly intervene in the case of a promising and deserving undergraduate.

VI. I have only to add that this College has for many years past done its best to keep and encourage poor men.

TRINITY COLLEGE, OXFORD.

I. (*a*) 18 Scholarships of 80*l.*; 8 Exhibitions of 60*l.* to 70*l.*; 4 or more close Studentships of 55*l.* Scholarships and Studentships tenable for four years; Exhibitions for three or four years.

II. No.

III. No.

IV. An Exhibition Fund from which payments can be made to members of the College who need assistance to complete their University course; private benefactions from time to time

V. (*a*) Very rarely, as candidates usually know the probable expenditure required for a University course.

(*d*) I remember none.

(*c*) The College has not infrequently supplemented Scholarships by grants from the Exhibition Fund and by loans.

VI. A considerable number of members of the University, including many of those who hold College Scholarships, have been awarded University Exhibitions by the Education Authority of the district to which they belong.

WADHAM COLLEGE, OXFORD.

I. 14 Scholarships, 1 of 86*l.*; 13 of 80*l.*, tenable, as a rule, for four years; 14 Exhibitions of 23*l.* to 60*l.*, tenable for four years.

II. No, with four special exceptions.

III. No.

IV. (*a*) A fund of about 36*l.* in the Warden's hands to assist deserving students.

(*b*) Frequently some assistance from private benefaction.

V. (*a*) and (*b*) I have never known of such cases. Sometimes deserving students get their Scholarships or Exhibitions supplemented by private benefaction.

VI. Our scholars almost always come from homes where some help is needed for a boy to come to the University. During my thirty years' experience I cannot recall a single case of a scholar or exhibitioner to whom the money was immaterial, and may also mention that in case of special need or desert help is given for residence during a fifth year. Each such case is decided on its merits.

LADY MARGARET HALL, OXFORD.

I. 3 Scholarships of 60*l.* to 35*l.* awarded annually, all tenable for three years with possible extension to a fourth.

II. and III. No.

IV. There is a Loan Fund common to all women students in Oxford.

V. (*a*) Yes, occasionally.

SOMERVILLE COLLEGE, OXFORD.

I. Awarded annually 1 Scholarship of 50*l.* for three years. Awarded triennially 2 Scholarships of 60*l.* for three years, 2 Scholarships of 50*l.* for three years (with possible extension for a fourth), and one of 40*l.* for three years. A few Exhibitions (1 to 3) of 20*l.* to 30*l.* for three years (with possible extension to a fourth).

Another Scholarship of 50*l.* is awarded without examination annually, usually to extend a three-years' Scholarship to a fourth year.

II. No.

III. No.

IV. (*a*) No permanent endowment.

(*b*) Friends of the College have occasionally supplemented Scholarships privately. There is the Loan Fund (see Lady Margaret Hall, Oxford).

V. (*a*) I don't remember such a case.

(*b*) One case. The scholar was (already) a graduate of another University, and the College thought it best in the scholar's own interest that she should accept a good teaching post offered her and resign the Scholarship.

VI. A scholar or exhibitioner may, for the benefit of others who need assistance, relinquish the whole or part of the emolument, while retaining the title.

ST. HUGH'S COLLEGE, OXFORD.

I. Annually, 1 Scholarship of 25*l.*; biennially, 2 of 30*l.*, 2 of 40*l.*, all tenable for three years and renewable for a fourth.

II. No.

III. No.

IV. None.

V. (*a*) No.

(*b*) and (*c*) Retirements would have occurred but for help through the College (private Loan Fund) or from the Loan Fund of the Association for the Education of Women in Oxford.

ST. HILDA'S HALL, OXFORD.

I. (*a*) Awarded annually 2 open Scholarships, tenable for three years (occasionally with extension to a fourth), 50*l.*, 30*l.* (or 2 of 40*l.*).

(*b*) In 1914 and every three years.

Dorothea Beale Scholarship of 50*l.* for pupils of the Ladies' College, Cheltenham, tenable for three years.

[Two other Scholarships (non-competitive) are awarded at Cheltenham to pupils of the Ladies' College, formerly, but now not always, every year, to be held at St. Hilda's Hall: viz., the Hay Scholarship of from 25*l.* to 45*l.* per annum for three years, and the S. Hilda's College Scholarship, of varying amount, same duration.]

(*c*) Exhibitions are occasional only. One of 30*l.* is now held for three years by a student who was third in the open competition.

II. No.

III. No.

IV. (*a*) None, except above Hay Scholarship, which is under the control of the Ladies' College, Cheltenham.

(*b*) None except a small fund once given but now exhausted. None for complete maintenance of students. Some are assisted (to the maximum of 50*l.*) by an old Students' Loan Fund, and they share with other women students in the benefits of the A.E.W. Central Loan and Grant Fund.

V. (*a*) Candidates have stated that they could only accept the larger of the two open Scholarships in about 5 cases, but I do not think they proved the successful ones. If successful they have sometimes managed to get loans from their own friends or Scholarship grants from the London or other County Councils, and their acceptance of a Scholarship has been contingent on this.

(*b*) Not actually.

(*c*) In one or two cases of difficulty the Hall has met them by rooms at reduced rate. Reduced fees were frequent until 1904, when competitive Scholarships were established; since then rare. Friends of the College have occasionally assisted individual students to remain at College.

VI. More Scholarships are badly needed, as many candidates of Scholarship or Exhibition standard cannot enter the Hall as commoners, and either go elsewhere as scholars to non-Oxford Colleges, or relinquish the idea of a University course. The paucity of Scholarships greatly increases the strain on girls who sit for several Scholarship examinations at different Universities in the same year.

CHRIST'S COLLEGE, CAMBRIDGE.

I. Average number of scholars and exhibitioners in residence, 40. Nominal value, 20*l.* to 80*l.*; but additional grants or reduction of fees, amounting to at most 20*l.*, are sometimes allowed privately in cases of poverty. Except there be distinct evidence of idleness, the Scholarship is retained normally to end of third year, sometimes continued to fourth, and occasionally to fifth year. The total average annual amount of the last six years is 1,800*l.*

II. No two *open* Scholarships or Exhibitions tenable together, but the value of a Scholarship may be increased. A *close* Scholarship, connected with a particular School, may be held with an open Scholarship.

III. No. The amount of a student's income from endowments of all kinds is, however, a factor in fixing the amount of his Scholarship, except in the case of those elected before coming into residence.

IV. No.

V. Candidates for Scholarships awarded before residence has commenced are asked to state the minimum value they are prepared to accept, and if they do not

come up to the necessary standard for that value they are not elected. In very rare cases such a candidate has written to say he finds he cannot come into residence on account of his Scholarship not being adequate.

VI. The fund for these benefactions arises partly from trust funds, liable to considerable fluctuations, but chiefly out of the corporate income, the amount payable out of this to the fund being one-quarter of the sum paid in the same year to the Master and Fellows; and this sum again has of later years been supplemented by grants from the Society. Our system has the great advantage of elasticity: the amount and duration of the Scholarship is within certain limits fixed by ourselves to meet the requirements of the special case.

The present system works well. No rich men hold Scholarships, and in nearly every instance the benefaction is necessary to enable the student to come to the University. The cases in which an intellectually deserving candidate fails to obtain a Scholarship are rare indeed; they hardly exist. It is most undesirable to attract by emolument poor men of ordinary ability. . . . The College badly wants funds for advanced students in specialised subjects.

CLARE COLLEGE, CAMBRIDGE.

I. There are offered annually 9 Scholarships at entrance values from 80*l.* to 40*l.*: also Exhibitions of 30*l.* In the first instance tenable for two years, but they are extended except in cases of idleness and want of progress.

II. Certain close Exhibitions and special trusts can be held with a Scholarship

III. No.

IV. A small fund is available. Research grants are also given

V. (*a*) Sometimes, but in such cases the emolument may be increased from the fund mentioned in the answer to 'IV.'

(*b*) Practically never.

(*c*) In deserving cases help has rarely failed to be forthcoming.

DOWNING COLLEGE, CAMBRIDGE.

I. Six Foundation Scholarships at least tenable till graduation standing of 50*l* to 80*l.*; a varying number of minor Scholarships and Exhibitions, tenable for one year, of 20*l.* to 50*l.*

II. No; but may be tenable with benefactions outside the College

III. No.

IV. No.

V. (*a*) I can recall no case.

(*b*) and (*c*) Additional aid from the College has prevented any actual retirement.

EMMANUEL COLLEGE, CAMBRIDGE.

I. The Foundation Scholarships: 4 Scholarships of 80*l.* per annum; 10 of 60*l.* per annum; and 22 of 40*l.* per annum.

(*a*) The *Scholarships* annually offered for competition before undergraduates come into residence are tenable for two years, and at the end of that time, subject to a favourable report upon the Scholarship and conduct of the holders, they may be continued or increased till the candidate has taken an examination qualifying him for the B.A. degree. The tenure is sometimes prolonged, but rarely beyond the fourth year, Students continuing study longer being provided for by Studentships mentioned below. Scholarships are awarded to other undergraduates also, if they distinguish themselves in the Annual College Examinations.

(*b*) 3 *Exhibitions* of 30*l.* are offered every year for open competition, and others awarded upon the results of the Annual College Examination in the same way as Scholarships.

(*c*) 2 *Subsizarships* also awarded every year to candidates who are in need of assistance, this need having to be satisfactorily proved by a statement of the parent's income and an authentication by some person of standing who knows the parents. For these there is no restriction of age, and subject to a satisfactory report of their conduct and progress, the holders proceed to a full sizarship at the end of their first year. The Sizarships, subject to the same conditions, are tenable for two years, and are worth 45*l.* a year.

(*d*) An *Exhibition* of 40*l.* to a *Student Teacher* upon the results of the examination held in conjunction with various colleges by the Drapers' Company, and if a number of good candidates present themselves, we generally award a second Exhibition of 30*l.*

(*g*) Besides these emoluments which are open to general competition, there are a few Exhibitions attached to particular schools, namely, Uppingham, Oakham, Derby, Ashby-de-la-Zouche, and Market Bosworth. But all with the exception of the Ash Exhibitions open to Ashby and Derby, are of small value. The Ash Exhibitions are worth 50*l.* a year.

II. The only case is that of the small close Exhibitions already mentioned which may be held with an open Scholarship.

III. On open Scholarships a limit of 80*l.* is imposed by Act of Parliament; no other limit is imposed, but it is very rarely that this amount is exceeded, though a candidate may have endowments from other sources.

IV. The Tutors have at their disposal a small fund to assist deserving students, and recently a former scholar has established a small fund to assist Scholars and Exhibitioners who may have difficulties in completing their course without assistance beyond what they receive from Scholarships.

V. (*a*) The only case known to me was that of an exhibitioner who announced from the beginning that he could come to College only if he was successful in obtaining help from his County Council, and this he failed to obtain.

(*b*) I have known of no case of a deserving beneficiary retiring during his course through lack of adequate means.

VI. The son of a poor man has now a better opportunity of entering Cambridge than he has had for many centuries past. In many small schools there seem to be now adequate means of preparation in mathematics and in some branches of Natural Sciences, but in such schools, if I may judge from my own experience, the literary education not infrequently leaves much to be desired, and on this side a good deal remains to be done in order to give satisfactory encouragement to those sons of poor men who have literary interests. In the circular regarding open Scholarships which is issued by the group of six Colleges to which Emmanuel belongs, attention is prominently called to the possibility of successful candidates being appointed to Honorary Scholarships without emolument, if they so desire. Applicants for Honorary Scholarships are, however, very rare. As the great majority of candidates are the sons of professional men, no doubt most parents cannot afford to relinquish the emolument.

GONVILLE AND CAIUS COLLEGE.

I. Scholarships offered annually: 3 of 80*l.*, 4 of 60*l.*, 4 of 40*l.*, 3 or more Exhibitions. These are tenable normally for three years, but may be, and frequently are, extended to four years. In addition to the above there is a Salomon's Scholarship for Engineering for 80*l.* which is offered triennially, and a special Scholarship in Music, value 60*l.* There are also Scholarships for post-graduate research; these vary in number and value according to varying needs. At present there are: 1 of 150*l.*, 1 of 120*l.*, 1 of 110*l.*, 2 of 100*l.*, 6 of 50*l.*

Bursaries vary according to special needs. There are at present: 1 of 50*l.*, 3 of 40*l.* (choral), 2 of 30*l.*, 1 of 25*l.*

II. Two benefactions are very rarely held together.

III. Yes. 180*l.*

IV. So far as I understand the question, we have no funds for the complete maintenance of students of exceptional promise. But the College habitually does privately help deserving students in need of pecuniary assistance.

V. (*a*), (*b*), (*c*) No.

JESUS COLLEGE, CAMBRIDGE.

I. Entrance Scholarships are limited by Act of Parliament to 80*l.*, and tenable for two years, but are ordinarily renewed and frequently increased in value. Scholarships (except some close Scholarships) are never less than 40*l.* and seldom exceed 80*l.*

II. Trust and open Scholarships may in general be held together, but the total amount of benefaction received by any individual seldom exceeds 80*l.*

III. No limit is imposed. I do not see how it would be possible to do so. But in determining the value of any Scholarship regard is paid to the total income of the scholar and his parents' means. Generally, this is only possible in the case of scholars already in residence.

IV. No; but privately many scholars (and undergraduates who are not scholars) receive assistance from the College or the Tutor.

V. (*a*) No, by the conditions: 'Candidates are required to state the value (usually

minimum) which they are prepared to accept, and are bound to accept any offer of the value they state.'

(*b*) Whether any scholars have *ever* retired for this reason I do not know; there has been no recent instance.

(*c*) The College sometimes gives assistance to scholars and others.

KING'S COLLEGE, CAMBRIDGE.

I. At the present moment the following grades of emoluments are held by students:

(*a*) Foundation Scholarships (48: 24 Eton, 24 open) awarded at entrance, some after (as Undergraduate Scholarships). The Laurence Saunders Scholarship also ranks as a Foundation Scholarship.

Of these 42 are now held in the College, of which 29 are of the annual value of 80*l.*; 5 raised by allowances to 128*l.*; 1 raised by allowances to 104*l.*; 1 reduced on prolongation to 40*l.*; 6 honorary. 21 of the scholars are B.A.s, 21 undergraduates.

(*b*) Minor Scholarships varying in number. Ten are now held: 9 of the normal value of 60*l.*, 1 raised by allowances to 84*l.*

(*c*) Exhibitions of various classes:

i. Entrance Exhibitions restricted to candidates in need of pecuniary assistance in order to obtain a University education, normal value 40*l.*, capable of augmentation up to 70*l.*

ii. Exhibitions specially endowed of various values, viz., Price Exhibition (2) of 40*l.*, capable of augmentation; Vintner Exhibition (Natural Science) of 70*l.*; Fielder (for Greek), tenable with another Exhibition, 32*l.*; Phillpotts, for son of a clergyman, 40*l.*; Morton, for a candidate for Holy Orders, 75*l.*; Soley, for candidate nominated by Drapers' Company, 70*l.*

iii. An Exhibition awarded annually to a member of the Cambridge Training College for Teachers, 30*l.*

iv. Ordinary Exhibitions awarded to undergraduates, of varying values. Of these, 22 are now held: 8 of the normal value of 40*l.*; 2 with the Fielder of 72*l.*; 6 augmented to 70*l.*; 1 augmented to 50*l.*; 1 Fielder held alone, 32*l.*; 4 30*l.*

(*d*) One Studentship (Augustus Austen Leigh), tenable with a Scholarship, 75*l.*

(*e*) Choral Scholarships varying in number: 4 are now held, of 80*l.* plus certain allowances, say 104*l.*

Tenure.—The normal tenure of entrance Scholarships is two years; prolongable for two years more in all. Tenure of undergraduate Scholarships: until the holder is of about four and a half years' standing from entrance; prolongable for two years more in all. Tenure of Exhibitions: (*a*) Entrance: two years, prolongable for a third; (*b*) Fielder, Soley, Phillpotts, Morton: three years; (*c*) others: One year, prolongable. Tenure of Choral Scholarships: usually three years.

II. The Fielder Exhibition is tenable with another Exhibition.

III. No; but in considering augmentation of Exhibitions account is taken of emoluments from other public sources held by the Exhibitioner.

IV. There is a fund, privately contributed and privately administered, for the assistance (not the complete maintenance) of needy students, not confined to Scholars or Exhibitioners.

V. (*a*) No such case is known to me.

(*b*) No.

MAGDALENE COLLEGE, CAMBRIDGE.

I. Number variable of Scholarships and Exhibitions. At present 24 in residence, besides 6 Sizars and 4 Subsizars. Scholarships are of 40*l.* to 80*l.*; Exhibitions generally of 30*l.*; tenure of both for two years, after which they may be prolonged and increased if the holders prove of sufficient merit. Sizarships are worth about 34*l.* and Subsizarships consist in the reduction of certain fixed charges, and admission to certain privileges at a given fixed charge.

II. A Scholarship or Exhibition is tenable with a Sizarship or Subsizarship, or with a 'private Exhibition' of 25*l.* (see IV.).

III. No.

IV. (1) Trusts amounting to about 120*l.* per annum from which small benefactions are made annually to poor and deserving students.

(2) Ordinands Fund of 50*l.* from which grants of 10*l.* are made to candidates for ordination requiring assistance.

(3) A private Exhibition Fund, providing 12 Exhibitions a year of 25*l.*; but in no case do we provide for the complete maintenance of students.

V. (*a*) Occasionally; but it seldom, if ever, happens that a candidate of real ability is obliged to decline an emolument on such grounds, as they are generally able to get additional help by means of School, or County Council, or City Company Exhibitions.

(*b*) No, not to my knowledge.

PEMBROKE COLLEGE, CAMBRIDGE.

I. Annually offered, 2 Scholarships of 80*l.*; 4 of 60*l.*; 4 of 50*l.*; and Exhibitions of 30*l.*, all tenable for three years and renewable for a fourth.

II. No.

III. No.

IV. A small fund is available.

V. (*a*) No.

(*b*) Only when sudden financial disaster has overtaken the parents.

(*c*) Private liberality has never failed.

PETERHOUSE, CAMBRIDGE.

I. See University Calendar. Number annually offered varies.

II. No, but grants in aid may be made from a fund for deserving students, but no grant would be made to an 80*l.* Scholar.

IV. Two private funds for deserving students administered by the Tutor with the cognisance of the Master; and a fund for the encouragement of research from which grants are made to students after graduation. No funds for complete maintenance of a student of exceptional promise.

V. (*a*) Cases may have occurred.

(*b*) I cannot remember any case.

TRINITY COLLEGE, CAMBRIDGE.

I. Our emoluments are divided into two groups: (1) those awarded before residence is begun; (2) those awarded to residents.

(1) A number, at present twelve, *entrance Scholarships* are awarded each December. Their value is 80*l.* a year, and they are tenable for two years of residence unless the holder is elected to a Senior Scholarship. Entrance Scholarships may be prolonged for a third year.

At present, ten *Exhibitions* of 40*l.* are also awarded annually before residence.

Both entrance Scholarships and Exhibitions may be increased by allowances in remission of fees to 100*l.* a year in cases of pecuniary need. Other regulations about them will be seen by the circular enclosed.

A certain number, at present twenty, *subsizarships*, tenable for three years, and worth about 35*l* per annum in remission of fees.

(2) *Emoluments awarded to residents.*

The College maintains at least eighty *Senior Scholarships*. Their value is 100*l.* a year before graduation and 80*l.* afterwards. They are tenable till five and a half years from commencement of residence.

An unspecified number of *Exhibitions* of 40*l.* a year tenable till graduation.

II. Subsizarships are tenable with Exhibitions and with entrance, but not with senior Scholarships. Exhibitions are not tenable with Scholarships, except in the case of fourth year (post-graduate) emoluments.

III. No limit is placed on the total emoluments; men often hold school or County Council Scholarships with our own.

IV. We do not undertake the complete maintenance of students. But the tutors have a gift and loan fund from which private gifts or loans can be made to meet temporary cases of need.

V. (*a*) Those awarded entrance Scholarships or Exhibitions never decline them. Sometimes Subsizarships are declined, but there the standard is lower.

(*b*) Retirement during the course is very rare or unknown. Help is constantly given from the Tutors' Funds.

(*c*) Answered above. Tutors' funds for gifts and loans.

TRINITY HALL, CAMBRIDGE.

I. About 300*l.* is awarded every year in Scholarships varying from 80*l.* to 40*l.* and Exhibitions of 30*l.*

II. No.

III. No.

IV. (*b*) A Fund bringing in a small annual income for supplementing Scholarships and giving assistance in such cases as are referred to in V. (*a*) (*b*) (*c*).

SELWYN COLLEGE, CAMBRIDGE.

II. The endowed Scholarships may be supplemented from the Exhibition Fund if the scholar is regarded as reaching a higher standard, but two benefactions cannot be held together.

III. No limit.

IV. No.

V. (*a*) 'Yes, from time to time. Now and then it has been possible to interest private individuals to come to the rescue before or after the candidate comes into residence; but the College has no means at its disposal for the purpose.'

VI. 'I should suggest that local authorities should be prepared to subsist *all* candidates from their area who have reached the requisite standard in an open competition, instead of making their support dependent on a further competition for a limited number of local Exhibitions.'

GIRTON COLLEGE, CAMBRIDGE.

I. Foundation Scholarships: 1 of 80*l.* for four years, 1 of 44*l.*, 3 of 40*l.*, 1 of at least 30*l.*, 1 of about 16*l.*

City Companies' Scholarships: 3 of 60*l.*; Clothworkers' Company (one awarded annually); (Skinners' Company), one of 50*l.*

One Gilchrist Scholarship of 50*l.* awarded annually, tenable here or at Newnham College.

Exhibitions: 1 of 30*l.* from Queen's College, Chester; 1 of 20*l.* from St. Leonard's School, St. Andrew's.

All the above, except the first, are tenable for three years; and except the Clothworkers and Gilchrist are awarded only every three years. Besides these, the College awards College Scholarships and Exhibitions each year.

II. Students are not allowed to hold more than one Scholarship awarded by the College. No regulations are laid down with regard to Leaving or County Council Scholarships, which a student may hold apart from the College.

IV. Scholarships or Exhibitions have sometimes been augmented privately, and also in some cases the Council has granted augmentation from College Funds.

V. I do not know of any.

NEWNHAM COLLEGE, CAMBRIDGE.

I. 5 Scholarships of 50*l.* for three years and 2 of 35*l.*, tenable for three years; 1 of 50*l.*, tenable for two or three years, and another of 50*l.*, tenable here or at Girton College for three years; 1 of 100*l.* for first year's students, tenable for three years; 1 of 40*l.* for one year for third-year students. A number of small grants, generally of 15*l.*, tenable with or without Scholarships; 5 grants of 5*l.* for books to students. All but one of above Scholarships are awarded annually.

II. Only as stated above.

III. No limit.

IV. A Loan Fund, from which as much as 30*l.* a year may be borrowed for three years. No other permanent endowment, though help may be given as stated above by means of the grants and Loan Fund and from private sources.

V. (*a*) No such cases.

(*b*) I believe not.

(*c*) Such resignations would be met by help from the grants and Loan Fund. By means of these a student holding the smallest of our Scholarships, one of 35*l.*, could make it up to 80*l.* (our fees are 90*l.*) with 15*l.* grant and 36*l.* loan. As a rule, however, we find that the students most in need of help have school Scholarships, and that their families are able to give them a little help.

UNIVERSITY COLLEGE, LONDON.

I. 44 Scholarships, varying from 10*l.* to 150*l.*; tenure varying from one to three years—'in two cases this may be raised to five.' Two Exhibitions of 57*l.* 15*s.*, tenable for three years; 2 Bursaries of about 16*l.*, tenable for two years.

II. Permission must be obtained to hold two College Scholarships at the same time, and in the case of the A. entrance Scholarships, the following Regulation obtains:

No student is permitted to hold an A. Scholarship concurrently with any other College Scholarship when the joint annual value of such Scholarships exceeds 50*l.*, except upon the special recommendation of the Professorial Board.

III. No.

IV. I have small sums placed at my disposal by friends of the College and members of the College Committee from time to time to help poor students, who are now greatly helped by County Scholarships.

V. (*a*) I have only known of one since my tenure of office here for the last nine years.

(*b*) In two cases during my tenure of office.

VI. I think it would be a good plan if all Scholarships, Exhibitions, and Bursaries were given practically as loans with the understanding that if and when a student, who had benefited from holding a Scholarship, found himself financially able to do so, he should return at least the sum that he had received. It has been done in one or two cases, but it should become a general policy and tradition.

KING'S COLLEGE, LONDON.

I. Studentships, 2 of 100*l.*; Scholarships (1 entrance), 1 of 30*l.* for one year (in alternate years); 2 of 25*l.* for two years; 2 of 30*l.* for three years; 2 of 25*l.* for four years, 2 (to Students of the College), 1 of 20*l.* for two years; 2 of 20*l.* for one year (first and second year's medical respectively), 1 of 20*l* for five years (training of medical missionaries). Exhibitions, 2 of 25*l.* for two years (1 entrance).

Theological, 6 Exhibitions of 50*l*, 5 Exhibitions of 20*l.*, and a few Bursaries at the discretion of the Dean.

II. Most of the above are entrance Scholarships, and not more than one can be held. The Regulations for the other benefactions make it impossible for more than one to be held at a time.

III. No limit.

IV. No regular fund, but Scholarships are sometimes supplemented by private benefactors.

V. (*a*) Yes, but not often.

(*b*) Yes, but not often.

(*c*) On rare occasions from general College funds.

KING'S COLLEGE FOR WOMEN, LONDON.

I. 2 Scholarships of 40*l.* for three years, each awarded once in three years; 1 of 30*l.* for one year (to second year Arts Students not necessarily of the College) in entrance Scholarships in Classics of 25*l.* for two years. Exhibitions of the value of 60*l.* for three years are open. Five Bursaries in Theology, covering fees for one session, are given to members of the Church reading for Certificate or Diploma, and who show that they are in need of financial help.

II. Two Scholarships may and at present are held by a single beneficiary.

III. No.

IV. None.

V. (*a*) No.

(*b*) No. Had such a case arisen, I think that the College would undoubtedly have assisted.

GOLDSMITHS' COLLEGE.

I. None, except when the London County Council award a free place. They are entitled to award 15 in consideration of their annual grant towards the maintenance of the College.

II. ———.

III. Not by the College Authorities.

IV. None.

V. (*a*) Application for free places is made to the County Council. I am not, therefore, in a position to answer.

(*b*) Not that I know of.

ROYAL HOLLOWAY COLLEGE.

I. Scholarships, 4 of 60*l.*, 7 or 8 of 50*l.* at entrance, tenable for three years. Bursaries not more than 6 of 30*l.*, tenable for three years. After not less than three terms' residence, 3 at least of 30*l.* for three years, and 1 of 60*l.* for three years.

II. If two (entrance and other) are held together, a reduction of 15*l.* is made.

III. No limit.

IV. None.

V. (*a*) No successful candidate has declined a Scholarship, but there have been several cases where a successful candidate would not have been able to take up a Scholarship without the help she received, either from her school, or from a County Council or other awarding body. In the case of the smaller Scholarships, namely, Bursaries, it has happened in several cases that these benefactions have been declined as a candidate was unable to furnish the remaining amount required for the fees.

(*b*) and (*c*) So far as I know, no deserving beneficiary has been allowed to retire from her course through lack of means; but there have been cases where this retirement would have been necessary if the students had not received help from a Loan Fund which has been established in connection with the College.

VI. I think that there is great room for increase in the help given by local education authorities to promising girls in order to enable them to go to College. Where an examination for Scholarships is strictly competitive, as in the case of our own entrance Scholarship Examinations, and, I believe, the entrance Examinations of all other Colleges, and where the funds are strictly limited, only a small number can be helped by the College to take up their career. I feel sure that the British Association Educational Section could do much to educate public opinion in this very important matter.

BEDFORD COLLEGE FOR WOMEN.

I. Entrance Scholarships, 1 of 60*l.*; 4 of 30*l.*; 4 of 50*l.* tenable for three years; 1 Scholarship, 60*l.* for three years; 1 Fellowship (? post-graduate), 50*l.* for two years. Residence Bursaries, which reduce the fees of residence by 14 guineas, are given to students who are unable to pay the full fees.

II. No two College Scholarships may be held together, but a College Entrance Scholarship may be held with a Scholarship or Exhibition from another source by special permission of the Council. Residence Bursaries are sometimes awarded to Scholars.

III. The question has not arisen.

IV. (*a*) No. There is a small 'College Fund' supported by voluntary contributions, from which grants are made to needy students, but these grants are not as a rule made to scholars.

(*b*) Scholarships are occasionally supplemented privately, but in no case does this provide for a complete maintenance of the student.

V. (*a*) and (*b*) Not during the last six years.

WESTFIELD COLLEGE.

I. 5 to 7 Scholarships annually of 35*l.* to 50*l.* for three years (last year 7 were awarded, each of 50*l.*); 1 permanent endowed Scholarship of 50*l.* for three years, offered every third year.

II. No.

III. No.

IV. Private help is in many cases given to supplement Scholarships, and also to help students who do not hold Scholarships. I have arranged for this privately.

V. (*a*) I believe that in some cases a Scholarship or Bursary has been declined where the winner has failed to gain another Scholarship elsewhere to supplement the one offered by the College.

(*b*) I think not. Help has been arranged in case of need.

(*c*) I have arranged privately for help by gifts or loans, and have received some gifts for this purpose from members of Council, old students, and friends of the College.

VI. In the award of Scholarships the written examination is not the only test, although it is necessarily the chief one.

UNIVERSITY OF DURHAM (DURHAM DIVISION).

I. At entrance (annually), 5 open Scholarships (to men and women) of 70*l.*; 1 of 40*l.*; 3 of 30*l.*; 3 of 20*l.* for one year, renewable for a second and third year; 1 of

70*l.*, 1 of 30*l.*, and 1 of 20*l.*, for women only; an Exhibition of 20*l.* for students of limited means; 3 second year Scholarships of 30*l.*, one restricted to those who do not hold any Scholarship or Exhibition, and 3 Exhibitions of 40*l.* and of 30*l.*, given on the results of the Final Examinations in Theology; also 1 of 40*l.* restricted to candidates for Honours in Theology. A number of close Scholarships and Exhibitions, ranging from 50*l.* to 8*l.*, all for one year (except two for three years).

II., III. No holder of a Foundation Scholarship can hold together with it any other Scholarships or Exhibitions (except two University and two close Scholarships for Graduates) which will with it amount to as much as 100*l.* a year.

V. (*a*) Occasionally, if awarded a Minor Scholarship.

ARMSTRONG COLLEGE, NEWCASTLE (IN THE UNIVERSITY OF DURHAM).

I. (*a*) At entrance, Exhibitions, 3 of 15*l.*, 1 of 20*l.*, each tenable for one year and renewable for a second year, subject to satisfactory conduct and progress; 20 Newcastle Corporation Exhibitions of free admission to Degree course for two years, renewable for a third under same conditions, and in very exceptional cases for a fourth year; with these may be provided Bursaries for successful candidates who, without such aid, would not be able to accept the Exhibitions; 2 Gateshead Corporation Exhibitions, giving free admission to Degree course (same conditions). County Council Scholarships and Exhibitions (restricted locally), 2 of 60*l.*; 2 of 50*l.*; 2 of 40*l.*, plus tuition fees, tenable for two years only; 3 yearly Scholarships of 50*l.* each in Marine Engineering, each tenable for three years, restricted to candidates who can produce satisfactory evidence that the amount will enable them to pursue their day courses, and that they would be unable to do so without this aid; 3 yearly Scholarships of 50*l.* each in Naval Architecture under same conditions.

(*b*) At close of first year, a Scholarship of 30*l.* or under for one year, plus remission of two-thirds of the class fees; 1 of 20*l.*, with similar remission for three years; 1 Scholarship of 15*l.* for one year; 1 of 13*l.* 10*s.* for one year (renewable under conditions for a second).

(*c*) At close of second year, 2 Scholarships of 40*l.* each for one year (with remission of fees), and other money rewards and prizes.

II. The second year's Scholarships and Exhibitions are not tenable with any other.

THE VICTORIA UNIVERSITY, MANCHESTER.

About 24 Foundation Scholarships, awarded by the University. A large number of entrance Scholarships, awarded by other bodies, varying from 25*l.* upwards; 12 Exhibitions of 15*l.* upwards; numerous prizes of books and money.

II. 'No . . . Scholarship or Exhibition awarded by the University shall be held together with any other . . . Scholarship awarded by the University or with any County Council School, without the express permission of the Senate. In the case of students who hold other . . . Scholarships or Exhibitions of any kind the Senate shall have power to withhold, either in whole or in part, payment of any . . . Scholarship or Exhibition awarded by the University. In the case of . . . Scholarships, Exhibitions, and Bursaries awarded by a Hall of Residence no such permission is necessary (University Scholarships are frequently held with County Council Scholarships up to a maximum of 75*l.* by special permission of the Senate).'

III. The Regulation stated above limits concurrent tenure, but there is no fixed maximum limit as to the amount a single beneficiary may hold laid down by the Regulations.

IV. Not at present. A small sum is set aside for assistance to deserving students to enable them to complete their course in case of special need arising.

V. (*a*) Yes, but not frequently.

(*b*) I cannot recollect such a case.

(*c*) Under very special circumstances a supplemental grant has been made from the Scholarship Suspense Account, or private loans have been given.

UNIVERSITY OF BIRMINGHAM.

I. (*a*) On entrance, 15 of remission of fees plus maintenance not exceeding 30*l.* for four years (city residents); 2 of 25*l.* for one year; 1 of 24*l.* for two or three years (Wolverhampton students); 1 of 50*l.* and 1 of 40*l.* for three years (Faculty of Commerce); 2 Bursaries of 45*l.* for three years (parents' income not exceeding 150*l.*); and one of 13*l.* (residents of Smethwick) for one year, renewable.

(*b*) Second and later years in Science, Arts, and Commerce, awarded mostly on Intermediate Examination, 1 Scholarship of remission of fees for three years (pupils of

Technical School); 1 of 40*l.* for three years; 1 of 25*l.* for two years, and 1 of 36*l.* for 1 year (limited to pupils from King Edward's Schools); 1 of 50*l.* and 1 of 40*l.* for three years (Commerce); 1 of 37*l.* for one year (Science and Metallurgy); 4 Exhibitions of 30*l.* for one year.

(*c*) Medicine, 1 of 21*l.* for 2 years; 1 of 14*l.* for one year (orphans of medical men); 4 of 10*l.* 10*s.* for one year on results of second, third, fourth, and final examinations.

II. No.

IV. We have no funds at our disposal of a permanent kind to supplement Scholarships for the complete maintenance of students of exceptional merit. We provide, however, out of ordinary revenue for maintenance up to 30*l.* per annum, in respect of 60 University Entrance Scholarships, tenable by candidates resident in the city

(*a*) The amount to be expended in any year on Scholarships and Bursaries respectively in any year is in the discretion of the Committee, and is determined by the applications received. Bursaries may provide for complete maintenance; their amount depends on the circumstances of the applicant and of his parents or guardians.

(*b*) No.

V. I do not remember any instances of (*a*) or (*b*).

THE UNIVERSITY OF LEEDS.

I. Entrance Scholarships, 2 of 20*l* and 1 of 21*l* for two years; 3 of 40*l* for two years for a third; 2 of 25*l.* and 1 of 35*l.* renewable; and a number of Scholarships on the award of public bodies. The Leeds City Entrance Scholarship Fund is now utilised 'for the purpose of extending the courses of deserving and necessitous Leeds students attending at the University.'

II., III. 'Power is reserved to declare a Scholarship vacant or reduce its value on the ground that the Scholar has previously or subsequently to his election acquired another Scholarship. In cases where students hold Scholarships the aggregate amount of which amounts to more than 75*l.*, the Senate reserves power to reduce them to this sum.'

IV. I am not quite clear as to the intention of this question. We have no fund which is necessarily used as a means of supplementing Scholarships, but some of the Scholarships and other awards may be given to students already holding some other Scholarship. Special grants have also been given by the University to Scholarship holders.

V. (*a*) (*b*) and (*c*) The information available is not sufficiently definite for a reply to be given to these questions If such cases have occurred, they have been very rare. Special grants have been made to Scholarship holders by the University, and private help has sometimes been forthcoming.

UNIVERSITY OF SHEFFIELD.

I. Scholarships and Exhibitions:

1	every year,	tenable during whole Medical degree Course,	122*l.* total value.
8	every year,	tenable for three years,	50*l.* a year.
2	,,	,, ,,	30*l.* a year.
12	,,	,, ,,	15*l.* first year, *plus fees remitted.* 20*l.* second year ,, 25*l.* third year ,,
6	(annual)	,, ,,	10*l.* first year, ,, 12*l.* 10*s.* second year ,, 15*l.* third year ,,
2	,,	,, ,,	20*l.* first year, ,, 25*l.* second year ,, 30*l.* third year ,,
4	every year	,, ,,	50*l.* a year ,,
1	(triennial),	tenable for three years,	50*l.* a year.
1	,,	,, ,,	21*l.* a year.
4	(annual),	,, ,,	Fees of Degree Course remitted.
1	,,	tenable for one year,	Fees in Engineering or Metallurgy remitted.
1	,,	,, ,,	20*l.*
1	,,	,, ,,	22*l.*
6	,,	,, ,,	50*l.* plus fees remitted.

In addition, the Surveyors' Institute offer 1 Scholarship of 60*l.* and 5 of 50*l.* for three years, tenable in this University.

UNIVERSITY OF BRISTOL.

I. Post-graduate Scholarships, 3 of 30*l.* to 34*l.* for one year; 1 of 25*l.*, for not exceeding three years; 1 of 20*l.* for one year; 'City Scholarships' consisting of the payment of all fees (varying in number and amount according to the applications and qualifications of candidates, and the Faculties they wish to enter), for one year renewable; 'City Bursaries,' under same conditions, for maintenance, purchases of books or apparatus.

3,000*l.* a year (approximately) devoted to 'City' Scholarships and Bursaries. In the Faculty of Engineering, 4 entrance Scholarships carrying free tuition for at least three years; 1 research Scholarship, value 50*l.* for one year, with free tuition; 3 entrance Scholarships from endowed Schools in the City (2 tenable only in the Faculty of Engineering), 30*l* for one year renewable. Several Exhibitions carrying free tuition in the Faculty of Engineering.

II. 'Not as a rule.'

III. No.

IV. No, except as above.

V. No.

UNIVERSITY COLLEGE, NOTTINGHAM.

I. 3 entrance Scholarships, each 30*l.* per annum, tenable for three years; a limited number of entrance Studentships, 12*l.* to 20*l.*, tenable for three years, for those whose means are limited; 1 Scholarship of 12*l.* for one year, and College Studentships (16 during 1912–13) of 10*l.* to 18*l.* awarded on results of Terminal and Sessional Examinations to College students who are in need of pecuniary assistance, tenable for one year, renewable. City Education Bursaries of 10*l.*, with remission of College fees, averaging 18*l.*

II. Under exceptional circumstances the College Council might sanction a Studentship being held together with Scholarship. It is possible for holders of College Scholarships and Studentships to hold Scholarships awarded by another body during the same period.

III. No. In awarding Scholarships, however, the pecuniary circumstances are in some cases taken into consideration.

IV. No.

V (*a*) Very few such cases have occurred.

(*b*) The College Studentships are designed to meet such cases.

UNIVERSITY COLLEGE, READING.

I. Scholarships and Exhibitions: Major open Scholarships, 2 of 69*l.*, 1 of 65*l.*, tenable for two years, renewable for a third. Two minor open Scholarships of 20*l.* to 24*l.* (*i.e.*, remission of tuition fees) under same tenure. Scholarships given by Halls of Residence, ordinarily of 40*l.*, under same tenure (see IV. below). Two minor Scholarships of 20*l.* to 24*l.* (*i.e.*, remission of tuition fees), ordinarily for three years, for candidates educated in Reading. One Scholarship of 60*l.* for three years, for candidates from Reading School. Two open Scholarships in Fine Art, of 30*l.*, for two years. Open Scholarships in Music, of 26*l.*, about 2 awarded per annum, ordinarily for three years. Exhibitions for the Secondary Education Course for women (complete or partial remission of the tuition fee of 20*l.*, for one year), one or two per annum. Certain other Exhibitions and Bursaries of less value.

NOTE.—In cases where Entrance Scholarships are held for three years, the holders are sometimes enabled to stay for a fourth year by means of a Secondary Education Exhibition or special assistance from a Hall of Residence (see IV. below).

II. Not two College benefactions in ordinary circumstances. Comparatively small Exhibitions, however, may be awarded to students holding other Scholarships or Exhibitions. The Committee governing our Halls of Residence also occasionally make small supplementary grants to students who already may be holding Scholarships or Exhibitions, if the cases seem to make such a course desirable.

III. We have no definite rule. . . . In this institution, during many years, I have only known one case in which it could fairly be said that perhaps the candidate was receiving too much money. In that case, he was not receiving Scholarships from the College at all, but derived them from other quarters.

IV. Our chief Hall of Residence for men has an endowment, the object of which is—provided that the working expenses of the Hall have been first defrayed —to enable Scholarships and Bursaries to be granted to students in residence

at the Hall. The full scheme is not yet in operation, but ultimately there should be, in a Hall of 77 students, about 6 scholars in receipt of about 40*l.* a year each, and possibly more holders of Exhibitions and Bursaries of smaller sums. We shall also be in possession quite shortly of an endowment to provide a Scholarship of 60*l.* a year, tenable by a candidate from R. School. Apart from these instances, we have occasionally given Scholarships temporarily out of our College income, or they have been provided by special gifts. I am not aware that we have ever given a Scholarship which involves 'complete maintenance.' In our opinion, such a course would be rarely desirable.

V. I do not remember a case of (*a*) or (*b*). The College has frequently, on the other hand, assisted students who could not complete their College course without some special assistance in addition to that which they might already be receiving from other sources.

VI. It is not quite clear to me what the precise purport of these inquiries is. Consequently, I am afraid that the information I have given may not be of much use. The most important observation, based on experience, that I can offer on t' of Scholarships would be this: that while entrance Scholarships se obvious purpose, far too much stress has been laid upon the importance large supply of them, without giving sufficient importance to their duration. is to say, it is of very little use for a local education authority or other body to give Scholarship for two years unless it has quite clearly made up its mind that—except the candidate fails in conduct or progress—the Scholarship will be extended, not only for a third year, but for a fourth. Extraordinary difficulty is experienced in persuading local authorities to extend any Scholarship for a fourth year, and yet it is precisely that fourth year which, in the case of University students, is the most important of all. Over and over again at this College our students have been placed in a difficulty in the final year of their course. The difficulty arises in any kind of University course, but I will give an instance of which I have had two recent examples. Two women students, holding Scholarships from local authorities, successfully obtained their degree after probably in each case three years' work, not more, and possibly less. These students wish to become teachers in secondary schools. Consequently, they wish to remain at the College for another year in order to go through a course of secondary training and get a certificate. Unless they do this, they will stand very little chance of getting posts for which trained candidates are in competition, and yet in both cases—the cases of the two Education Committees—opposition is shown to the extension of the Scholarships for these purposes. In one case, the Education Secretary writes to say that the course of secondary training appears to him to be similar to a course of preparation for a civil service examination, and, in his opinion, not a course for which a Scholarship should be continued. The same Secretary, I believe, puts into his advertisements for vacancies in the staffs of his county secondary schools that only trained candidates need apply. At this College we have recognised that the most imperative need of all is for Scholarships that would take effect during the third and fourth and even fifth years of a student's stay with us. We consider that these are more important than entrance Scholarships, and that nothing would benefit a University institution more than for it to be known that, notwithstanding a comparatively small supply of entrance Scholarships, there is a probability that any hardworking and promising student will be enabled to complete a long course of study, including probably a period of post-graduate study. We have already decided that such funds as we possess available for such purposes will be used in accordance with these principles when the College becomes a University in two or three years' time.

UNIVERSITY COLLEGE, ABERYSTWITH.

I. 37 Scholarships and Exhibitions, 1 of 54*l.*; 3 of 40*l.*; 1 of 35*l.*; 1 of 27*l.*; 4 of 30*l.*; 1 of 20*l.*; 2 of 15*l.*; 14 of 10*l.*; 1 of 6*l.* Of these, 1 is tenable for four years, 18 for three years, 12 for two years, 6 for one year.

II. No two of these are tenable together, but students may hold them together with Scholarships from other sources outside the College.

III. No limit is imposed on the annual income derived from emoluments of all kinds by a single beneficiary.

IV. There is no benefaction for the complete maintenance of students of exceptional promise.

V. (*a*) Cases have occurred. 'Occasionally the College can be of assistance by obtaining private aid, but as a rule this is not possible.'

(*b*) 'Cases have also occurred of deserving beneficiaries retiring during their course through lack of adequate means; but in most cases they have taken posts in schools or otherwise, and have subsequently returned to College to complete their course.'

(*c*) 'The Principal and Registrar have at their disposal a small loan fund from which they make periodical grants to deserving students, free of interest.'

UNIVERSITY COLLEGE, BANGOR.

I. Entrance Scholarships, 1 of 40*l.*; 1 of 30*l.*; Exhibitions, 1 of 20*l.*; 4 of 10*l.*, tenable in the first instance for three years, but may be extended for a fourth; and a number of limited Scholarships and Exhibitions, the highest of 30*l.*, the longest tenure three years.

II. 'No two College benefactions can be held together.'

III. No limit has hitherto been imposed.

IV. We have no permanent endowment or benefaction for this purpose. There is, however, a 'Loan Fund' from which advances (repayable without interest) are made to students who are unable without such assistance to complete their courses.

V. (*a*) We do not know of any case . . . great sacrifices are often made by the parents of students in order to enable their children to come to College, and in many cases friends in the locality from which a student comes render assistance.

UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE, CARDIFF.

I. 59 Scholarships and Exhibitions: 6 of 10*l.*, 1 of 15*l.*, 12 of 17*l.* 1*s.*, 18 of 20*l.*, 11 of 25*l.*, 2 of 27*l.*, 3 of 35*l.*, 2 of 40*l.*, 3 of 50*l.*, and 1 of 70*l.* Of these 23 are tenable for one year (of which 14 are renewable), 2 for two years, 34 for three years. There are also 72 County Free Studentships (60 tenable for three years, and 12 for one year), covering fees at the College, to which maintenance allowances are attached by the counties concerned. These College Scholarships, Exhibitions, and Free Studentships do not represent the annual awards to students at entrance, but the total number which may be held by all students in one session, and some of them are awarded for post-graduate work.

II. and III. (1) Students may hold College Scholarships together with Scholarships from sources outside the College.

(2) By order of the Council, no student may receive more than 50*l.* from the *College* in any one year. An Exhibition is reckoned as 10*l.* out of this sum. The above Scholarship of 70*l.* is a Special Scholarship not coming within the terms of this order.

IV. There is no benefaction for the complete maintenance of students of exceptional promise.

V. No case has come to our knowledge. There is a Loan Fund for assisting meritorious students which has been provided by subscriptions. Grants, free of interest, are made from this Loan Fund by the Principal and the Registrar.

For the Bursaries, etc., at the Scottish Universities, see Parliamentary Paper 411, 11 Dec. 1912.

The CARNEGIE TRUSTEES grant assistance to students solely in respect of payment of class fees.

UNIVERSITY OF ST. ANDREWS.

I. The value of Bursaries on entrance, as given in the Parliamentary Paper, varies from 6*l.* 10*s.* to 50*l.* per annum, and their tenure varies from three to eight years. In addition to these, 7 Bursaries in the second year of 16*l.* 5*s.* to 30*l.*, tenable for two or three years, and 2 in the fourth year of 20*l.* and 45*l.* respectively, are awarded.

An additional entrance Scholarship of 30*l.* for four years has been founded for women students. As a rule, the Bursaries on entrance run only for three years, in a few cases for four; and 6 Scholarships of 80*l.* for one year, 4 of 50*l.* for two years, and 1 of 50*l.* for one year, and 4 of 80*l.*, tenable at Oxford or Cambridge for four years, are not included in the White Paper (some are post-graduate).

II. Not as a general rule; but in the case of second-year Bursaries, they may be awarded to a student, notwithstanding he already holds a Bursary gained at entrance.

III. No general rule imposing a limit. The rule just quoted to some extent secures that there will be no undue accumulation of Bursaries in one person. As regards outside Bursaries over which the University has no control, the case is provided for by a rule that no one shall be entitled to hold a Bursary in the University with any outside Bursary yielding an annual income greater than 20*l.*, and tenable during a period of three years. The University authorities may at any time alter this regulation.

IV. There is a small fund raised some years ago to enable Foundation Bursaries to be supplemented. Two other funds left to the University without any reservation may be devoted to the augmentation of existing Bursaries.

I do not remember any case, however, where money from any of these sources has been drawn upon for the complete maintenance of any student. Of course, in Scotland, the existence of the Carnegie Fund Trust for the Universities of Scotland, which up till recently practically paid the class fees due by a student qualified to obtain that benefit, forms a considerable supplement to the Bursary Fund. Students may have their fees paid and hold a Bursary of from 15*l.* to 40*l.* a year, in which case the latter source of income provides for their maintenance.

V. (*a*) and (*b*) I do not recollect such a case within my experience. Of course, the cases are numerous in which candidates who were relying on assistance from the Bursary Funds have been obliged, owing to their failure to obtain a Bursary or to some other financial casualty, to defer entering the University, or to leave the University midway in their career. No statistics and no definite note has been kept of such cases. I do not think that in the case of a student of exceptional ability it could easily occur.

(*c*) The University is enabled, out of a fund made up of the income from Bursaries which from various causes have lapsed, to provide for the encouragement of students of small means where they are known to have merit; and that more particularly where, having struggled on through the curriculum for an ordinary degree, the student desires to obtain honours. The University Court have provided, to meet that case, for grants being made to students of the fourth and fifth year of study. As a rule, the ordinary Bursary or University Scholarship at entrance runs only for three years, in a few cases for four.

UNIVERSITY COLLEGE, DUNDEE.

I. Bursaries, entrance, 12 of 15*l.*; second year, 4 of 20*l.*, 2 of 15*l.* Third, fourth, and fifth years each one of 20*l.*, all tenable for one year only. Other Scholarships and Bursaries in the gift of other bodies or patrons tenable, held mostly at this College, are one of 60*l.* for two years; 2 of 25*l.* for three years; 1 of 25*l.* to 30*l.* for three years; 5 of 40*l.* for three years.

II. As a rule not; but exceptions are allowed in special deserving cases.

III. This question is answered in the negative in reference to Answer II.

IV. No.

V. (*a*) and (*b*) No.

VI. A Committee of the College Education Board is at the present moment investigating the whole question of the awarding and tenure of Bursaries concerning the College, whose Report is expected before the close of the current academical year.

UNIVERSITY OF GLASGOW.

I. Reference only to Parliamentary Paper. For undergraduates are provided a large number of Bursaries of which few are over 40*l.* a year, 60*l.* being the highest; tenable mostly for three or four years (the longest tenure is seven years). Exhibitions and Scholarships are all post-graduate.

UNIVERSITY OF ABERDEEN.

I. Reference to Parliamentary Paper. Maximum value, 38*l.*; tenure one, two, or three years, mostly four years; in addition to post-graduate Scholarships there are 280 Bursaries of the total annual value of 5,750*l.* A fund of 322*l.* is awarded each year in four sums to students who are in special need of pecuniary assistance to prosecute their studies at the University.

II. No; but a student may hold a Bursary of the University along with such a Scholarship as the Ferguson, which is open to all Scottish Universities.

III. No.

IV. No.

V. (*a*) and (*b*) Not that I am aware of.

UNIVERSITY OF EDINBURGH.

I. *Scholarships, &c.* The total annual value of the University Fellowships, Scholarships, Bursaries and Prizes amounts to about 19,790*l.*, viz., in the Faculty of Arts, 10,300*l.*; in the Faculty of Science, 1,190*l.*; in the Faculty of Divinity, 2,010*l.*; in the Faculty of Law, 940*l.*; in the Faculty of Medicine, 5,230*l.*; and in the Faculty of Music, 120*l.*

The *Fellowships* and *Scholarships* (chiefly for advanced students or graduates) number about 105.

The years of tenure range from one to three or four, in one case (the Shaw Philosophical Fellowship) reaching five.

The *Bursaries*, about 307, with very few exceptions, are tenable only by undergraduates in the respective Faculties: Faculty of Arts, 220 (several being tenable also in other Faculties); Faculty of Divinity, 40; Faculty of Law, 9; Faculty of Medicine, 38. Total 307.

The annual values range from 10*l.* to 50*l.*, the greater number being from 20*l.* to 30*l.*

The period of tenure, in most instances, three or four years.

II. Save in a few exceptional cases, it is not permitted to hold, at the same time, more than one University Scholarship or Bursary.

III. No; although in a few instances eligibility for a Scholarship or Bursary is conditional upon total income not exceeding a specified sum.

IV. (*a*) No.

(*b*) The Carnegie Trust gives annual allowances towards payment of class fees, to students (irrespective of other benefactions being received) who fulfil certain conditions as to age, nationality, preliminary education, &c. The allowances in the various Faculties are as follows:—In Arts (ordinary), 9*l.* a year, for three years, or (honours) 9*l.* a year, for four years; in Science, 12*l.* a year, for three years; in Medicine, 15*l.* a year, for five years: in Law, Divinity and Music, 6*l.* a year, for three years.

V. This question seems hardly applicable to the conditions of the Scottish Universities.

TRINITY COLLEGE, DUBLIN, AND UNIVERSITY OF DUBLIN.

I. 2 Studentships of 100*l.* a year each, tenable for five years. 70 Foundation Scholarships given at various stages, and tenable till M.A. standing, value 18*l.* 9*s.* 4*d* yearly, with exemption from Arts Fees (16*l.* 16*s.*), free Commons, say 30*l.*, and half rent for rooms in College, say 5*l.*, yearly. Non-Foundation Scholarships for women, at present 14, value 30*l.* yearly, under same tenure. In no case are these Scholarships to exceed five years. Senior Moderator Scholars, at present 30 of 10*l.* yearly. Twelve Senior Exhibitions of 20*l.* and 4 of 15*l.* yearly, tenable for two years. 12 Junior Exhibitions of 20*l.* and 4 of 15*l.* a year, tenable for two years. 12 Roll Keepers, Markers, etc., from 7*l.* to 20*l.* yearly, and Provost's Marker, 45*l.* yearly. 30 Sizarships for men and women,[1] 5 Reid Sizarships, and at present 6 Sizarship Exhibitions, and numerous other Exhibitions varying from 5*l.* to 60*l.* yearly.

II. Yes.

III. No limit.

IV. None for complete maintenance.

V. (*a*) and (*b*) No.

UNIVERSITY COLLEGE, CORK.

I. Entrance Scholarships, College 12 (3 of 40*l.*, 6 of 30*l.*, 3 of 20*l.*) for one year; 3 Honan (for those whose financial position is such that it would be impossible to obtain a course of instruction for a University degree without this aid); 3 of 50*l.*, renewable up to a fifth year.

Later years, Faculties other than Medicine and Engineering, 2 of 40*l.*; 2 of 30*l.*; 4 of 20*l.* for second year, renewable for third year. Engineering, 1 of 30*l.* for second year; 1 of 30*l.* for third year. Medicine, 3 of 30*l.* for second year; 3 of 30*l.* for third year, 3 of 30*l.* for fourth year, renewable for fifth. Law, 1 of 10*l.*, awarded at end of first year. Exhibitions may be awarded in every case to students of merit who have failed to obtain Scholarships.

[1] Students of limited means, exempt from Arts Fees; men having Commons free of expense, and women an allowance of 30*l.* in lieu of Commons.

County Council Scholarships, tenable in the College:—

Cork: 10 of 24*l.*, tenable for three years and renewable for a fourth or fifth; increasable from the Reserve Fund up to 50*l.* in such cases as may seem advisable; 100*l.* per annum, rising in the third year, to be allocated to Bursaries of lesser value to promising students, not worthy of Scholarships.

Kerry: 2 of 50*l.*; 3 of 30*l.* (restricted in respect of calling and means of parents) for one year, renewable for a second to a third year.

Waterford: 3 of 50*l.* and 1 of 30*l.* for three years (may be extended to fourth and fifth year).

Other Scholarships are offered by the County Councils of *Limerick* and of *Tipperary* (North and South Ridings).

II. No. But there are practically no outside ones that could be tenable with ours, except possibly from Trinity College, Dublin.

IV. (*a*) Only in the case of the County Cork scholars, who may be helped from the 'Reserve Fund' 'where necessary' in the judgment of the President of the College.

(*b*) No regular stream.

V. (*a*) and (*b*) Yes.

(*c*) In some cases by private beneficence.

VI. It is desirable that there should be at the disposal of the College a fund earmarked to supplement Scholarships, &c., for the complete maintenance of students of exceptional merit.

THE QUEEN'S UNIVERSITY, BELFAST.

I. (*a*) Foundation Scholarships, junior, 40 of 40*l.*, tenable for one year; 3 of 40*l.*, 6 of 30*l.*, 4 of 20*l.*, 3 of 15*l.* in the Faculty of Medicine; 3 of 20*l.* in the Faculty of Law, and 6 of 20*l.* in the Faculty of Commerce. Extra Scholarships may, in special circumstances, be offered for competition among Art(s?) Students entering upon their second or third year.

(*b*) Private endowment, 1 of 20*l.*, on entrance, for one year, renewable for a second and a third year; 3 Sullivan Scholarships of about 40*l.*, for three years, on entrance, restricted to national teachers or assistant teachers; 2 of 20*l.* for one year; 1 (Megaw) of about 40*l.* for one year (restricted to Christians); 1 of about 40*l.*, payable in three annual instalments; 1 of 10*l.* and 1 of 5*l.* in Commerce, tenable for two years; 1 of about 27*l.* for women, payable in three annual instalments; 1 Exhibition of 27*l.* for Undergraduates in Arts; 2 entrance Exhibitions (Drennan and Tennent) of 5*l.* each at entrance.

(*c*) In addition to these the City and County Borough of Belfast offers annually 4 Scholarships of 40*l.* annually for three years (which may be extended to a fourth or fifth, in the case of exceptional merit or excellence), tenable by matriculated students of the University. Candidates must show that they are in need of assistance.

(*d*) The following County Scholarships and Bursaries are also tenable at any University in Ireland, all for three years, in the University of Belfast, Antrim, 2 of 40*l.*; Donegal, 2 of 45*l.*; Kildare, 4 of 50*l.* (Catholics excluded); Monaghan, 3 Scholarships of 50*l.* and 3 Bursaries of 25*l.* (Catholics excluded); Westmeath (only tenable in the University of Belfast and the National University), 3 of 50*l.*; Wexford, 3 of 50*l.*, and 3 Bursaries of 25*l.* (Catholics excluded).

II. 'Except where otherwise specified, no Scholarship can be held in conjunction with Scholarships or Exhibitions.' A Sullivan or Megaw Scholarship, or a Drennan or Tennent Exhibition may be held with a Foundation Entrance Scholarship.

V. (*a*) and (*b*) Not to our knowledge.

APPENDIX II.

LIST OF TOTAL EMOLUMENTS HELD ON ENTRANCE BY STUDENTS IN THE UNIVERSITIES OF OXFORD AND CAMBRIDGE.

(Arranged in Order of Values.)[1]

A. *Oxford.*		B. *Cambridge.*	
No Emoluments Accepted	1	£20	2
£20	2	25	3
21	1	30	19
30	7	32	1
33	1	33	1
40	10	35	5
50	10	40	21
60	10	50	7
70	2	57	1
75	1	60	14
80	45	65	2
82 10*s.*	1	67	1
89	4	70	5
90	11	74	1
100	19	75	3
105	4	80	15
106	3	85	3
110	7	90	11
115	1	91	2
117 14*s.*	1	93	1
120	15	95	1
121	1	100	16
125	4	105	2
126 1*s.* 6*d.*	1	110	9
130	17	111	1
133 16*s.* 8*d.*	1	112	1
135	3	115	6
136	1	120	6
140	10	125	3
143	1	130	8
145	1	135	6
150	12	138	1
151	1	140	7
152	1	145	3
155	2	150	13
160	5	154	1
170	6	155	2
180	5	160	5
185	1	164	1
230	2	170	1
		175	1
Total	231	178	1
		180	3
		188	1
		190	3
		300	1
		Total	221

[1] Compiled from the detailed tables supplied on behalf of the Universities 'Minutes of Evidence' to the Royal Commission on the Civil Service, Jan. 9–24.

Museums.—Interim Report of the Committee, consisting of Professor J. A. GREEN (*Chairman*), Mr. H. BOLTON *and* Dr. J. A. CLUBB (*Secretaries*), Dr. BATHER, Mr. C. BUCKMASTER, Mr. E. GRAY, Professor S. F. HARMER, Mr. M. D. HILL, Dr. W. E. HOYLE, Professors E. J. GARWOOD *and* P. NEWBERRY, Sir RICHARD TEMPLE, Mr. H. H. THOMAS, Professor F. E. WEISS, Dr. JESSIE WHITE, Rev. H. BROWNE, Drs. A. C. HADDON *and* H. S. HARRISON, Mr. HERBERT R. RATHBONE, *and* Dr. W. M. TATTERSALL, *appointed to examine the Character, Work, and Maintenance of Museums.*

THE Committee reports that during the year it has carried out extensive inquiries upon various aspects of museums in relation to Education. Sectional Reports upon the museum needs of school children, students, and the general public have been drawn up by sub-committees, and afterwards issued to all the members.

Dr. F. A. Bather and Mr. H. H. Thomas attended the meetings of the Congrès de l'Association Française at Havre, and conferred with French representatives upon subjects covered by the terms of reference of the Committee. Dr. Bather also communicated a paper upon the 'Commission de l'Association Britannique sur les Musées.'

Mr. H. Bolton and Dr. W. M. Tattersall visited the chief Australian and American museums during the course of their overseas journey to and from Australia last year. In every instance they received a warm welcome from their colleagues and all possible assistance in pursuing their inquiries. The American museums proved especially profitable, as in numerous cases a thorough co-operation has existed for years between the museums and every grade and kind of educational effort.

A lengthy questionnaire was prepared by the Committee in the hope of its adoption by the House of Lords for departmental issue to all museums Owing to the war, this was not possible, and the questionnaire was therefore issued by the Committee on its own responsibility to all provincial museums in the British Isles. About one hundred and forty replies have been received, and are now under consideration.

A special questionnaire upon classical education in relation to museums has also been issued.

A joint conference between the Committee and the Museums Association was held at the Victoria and Albert Museum, London, on July 9, when Professor J. A. Green introduced the question of the museum in relation to schools. Attention is also being directed to the question of the relation of museums to universities.

The Committee hopes to complete its labours during the course of the coming year, and asks to be reappointed with a grant of 15*l.*, and with the addition to its number of Sir Henry Miers, F.R.S.

Nomenclature of the Carboniferous, Permo-Carboniferous, and Permian Rocks of the Southern Hemisphere:—The Committee consisting of Professor T. W. EDGEWORTH DAVID (*Chairman*), Professor E. W. SKEATS (*Secretary*), Mr. W. S. DUN, Sir T. H. HOLLAND, Mr. W. HOWCHIN, Mr. G. W. LAMPLUGH, *and* Professor W. G. WOOLNOUGH, *appointed to consider the above.*

REPORT OF THE AUSTRALIAN MEMBERS OF THE COMMITTEE.

I.

A TABLE (II.) of a suggested correlation of these rocks and also the following points were presented for discussion and report by the Honorary Secretary, Professor E. W. Skeats, The University, Melbourne:

1. Is a single name desirable for all Australian Permo-Carboniferous rocks? *i.e.*, should we abandon local terms such as Bowen, Gympie, Bacchus Marsh, &c.?
2. If so, or if a comprehensive name in addition to local names is desirable, should the name be a general one, *i.e.*, Permo-Carboniferous, Carbo-Permian, or Permian?
3. If a local name be preferred, which name is most suitable? It has been suggested that since the Glacial series was first discovered by Selwyn in the Inman Valley in South Australia they might be called 'the Inman series' or that a suitable aboriginal name from that district might be chosen. If the latter, what is a suitable name?
4. Can we be certain that the prominent Glacial Conglomerate is always on the same geological horizon, *i.e.*, is it everywhere contemporaneous? The presence of two or more Glacial Conglomerates in Victoria and New South Wales suggests a repetition of Glacial conditions not necessarily with the same time-interval between them, since at Bacchus Marsh in Victoria several conglomerates are intercalated among the shales and sandstones of the one series, while in New South Wales the Lower Marine prominent Glacial horizon is followed by the Greta series, and then Glacial boulders recur in the Upper Marine series. In other areas in Victoria, New South Wales, South Australia, &c., where a Glacial bed rests unconformably on older rocks and is not conformably overlain by fossiliferous rocks, we have no stratigraphical or palæontological guide and commonly *assume*, and are unable to demonstrate, that these widely separated occurrences are on the same horizon as those of Bacchus Marsh in Victoria and the Hunter River in New South Wales. Are we safe in making this assumption?

II.

Correlation-Table of Permian, Permo-Carboniferous, and

By Professor E. W. Skeats, D.Sc., A.R.C.Sc.,

Horizon	New South Wales	Victoria	Queensland	West Australia	South Australia and Northern Territory
Permian		Schizoneura Sandstones of Bacchus Marsh?	Upper Bowen Series?		
	Newcastle Series with Glossopteris			Collie River Coal Series with Glossopteris	
	Dempsey Series				
	East Maitland or Tomago Series				
Permo-Carboniferous	Upper Marine Series with Glacial Boulders				
	Greta Series with Gangamopteris	Gangamopteris Sandstone of Bacchus Marsh	Lower Bowen and Dawson Coal Series	Gascoyne Worramel and Minilya Series with Lyons Conglomerate at base	Victoria River and Arnhem Land Series (N. Terr.) with Glossopteris?
	Lower Marine Series with Glacial Conglomerate	Tillites, &c., of Bacchus Marsh Derrinal, &c.	Gympie Series with Gangamopteris		Tillites, &c., of Hallett's Cove, Inman Valley, &c.
Carboniferous	Rhacopteris-bearing Series	Avon River, Mansfield, and Grampian Sandstones? with Lepidodendron australe	Star Series with Lepidodendron australe	Kimberley Series with Lepidodendron?	
	Lepidodendrum volkheimianum-bearing Series				
Upper Devonian?	Mt. Lambie Series	Iguana Creek Beds? with Cordaites			

Note.—Junctions between Devonian

Junctions between Carboniferous and Permo-Carboniferous are conformable in South part

Junctions between Permo-Carboniferous (Permian?) and Mesozoic are conformable

Carboniferous Rocks of the Southern Hemisphere and of India.
F G.S. (Secretary of Committee).

Tasmania	New Zealand	South Africa	South America	Antarctica	India
Knocklofty Series with Vertebraria indica ?	Wairoa Series? (Park), Kaihiki Series (Park)?	Lower Beaufort Series with Pareiasaurus and Glossopteris	Schizodus Series of Brazil with Mesosaurus	Beacon Sandstone ?	Panchet Series ?
	Aorangi Series (Park) ?		?		
	Maitai Series? (in part) (Park)	?			?
Sandy Bay Series				Beacon Sandstone ?	Damuda Series ?
Mersey Series		Ecca and Kimberley Series with Mesosaurus	Santa Catharina Series of Brazil and Argentine with		
Glacial Series of Wynyard, Eaglehawk Neck, &c.		Tillites, &c., of Dwyka Series	Orleans Glacial Conglomerate at base	?	Talchir Series with Glacial Conglomerate at base
		Witteberg Series			
		Bokkeveld Series ?			

and Carboniferous are conformable.
of South Africa, discordant in North part of South Africa, and in New South Wales.
in South Africa, India, and New South Wales (slightly discordant in places).

5. Is the correlation usually made with other areas in the Southern Hemisphere and with India surely and definitely established? For instance, is the correlation suggested in the included table agreed to by members of the Committee? Reasons for agreement or disagreement are requested.

6. Are the relations between Devonian and Carboniferous rocks in the Southern Hemisphere everywhere conformable? If not, where do discordances occur?

7. Further statements as to regions of discordance and of accordance of the junction between Carboniferous and Permo-Carboniferous rocks in Southern Hemisphere are requested.

8. In New South Wales (in places), in South Africa and in India, the Permo-Carboniferous merges into the Mesozoic apparently without break. This may also occur at Bacchus Marsh. This raises the question as to defining the upper limit of Permo-Carboniferous and its distinction from Permian.

III.

Discussion of the above Notes and Table by Professor T. W. Edgeworth David, *C.M.G., D.Sc., F.R.S., &c. (Chairman of Committee).*

Question 1. Local terms such as Bowen (system name), Gympie (series name), Bacchus Marsh (stage or series name), might with advantage be retained, as they are useful for describing local developments of rocks which while not necessarily synchronous (*e.g.*, 'Bowen' probably takes in far more than 'Bacchus Marsh') are to be grouped within the general term Permo-Carboniferous A single name to take in all local divisions ('Bowen,' &c.) is desirable.

Question 2. Permo-Carboniferous had better be retained for the present. It was suggested by R. Etheridge, Jun., in 1880 (see 'Proc. Roy. Phys. Soc. Edinburgh,' 1880, vol. v. p. 319), where R. Etheridge's report is recorded on the first collection of fossils sent to him by Dr. R. L. Jack. Unfortunately specimens from the Star beds (typically Carboniferous [T. W. E. D.]) were mixed up with Gympie and other typical Permo-Carboniferous fossils in this collection. Dr. Jack at this time thought the Star beds to be newer than the Gympie, but this view has now been given up, and the Star beds are considered older than the Gympie. But although the true Carboniferous (Star beds) are now eliminated from R. Etheridge's original Permo-Carboniferous system, he considers that there is still a sufficiency of Carboniferous types in other true Permo-Carboniferous areas in Queensland to justify the retention of the term for all formations within the Commonwealth from the basal Glacial beds up to the topmost beds which contain any trace of the *Glossopteris* Flora.

The recent discovery in the Seaham district of New South Wales of Glacial beds at the base of the Lower Marine series passing downwards into *Rhacopteris* (*Aneimites*)-bearing shales, with in one case a fragment of *Aneimites* in the shales associated with the lowest Glacial bed,

seems now further to justify the retention of the term Permo-Carboniferous.

Question 3. If a general local name is to be given, the name 'Hunterian' (from the type-area of the Hunter River) has a prior claim, and probably a stronger claim than any other, as (*a*) It was suggested for this application by the late Professor Ralph Tate ('Report Australian Association for the Advancement of Science for 1900,' published 1901, p. 63 of his Presidential Address), and (*b*) The Hunter area is the first type-area in Australia (that is an area where the whole system from basal Glacial beds to top of the Newcastle series are developed) to be described. This description has been given by the Rev. W. B. Clarke ('Sedimentary Formations of New South Wales,' &c.).

As regards the term 'Inman Series,' if it is intended to restrict it entirely to the Glacial stage of the Permo-Carboniferous system there are no serious objections to its use, but it seems to me that—

(*a*) in view of the fact that no fossils whatever have as yet been found in these beds, and

(*b*) that the former Government Geologist of South Australia (H. Y. L. Brown) was of opinion that the beds were of Mesozoic age, and that the present Government Geologist (L. K. Ward) still questions their age as being Permo-Carboniferous (*v.* his Geological Map in 'Handbook of South Australia' prepared for the B.A.A.S. visit in 1914) and in view also of the fact that

(*c*) there is more than one Glacial horizon in the Permo-Carboniferous system

—it would be distinctly preferable to use the terms 'Inman,' 'Bacchus Marsh,' 'Wynyard' stages or series, 'Lochinvar' stages or series, 'Lyons Conglomerate' stage, etc., for local developments of the basal Glacial beds. (Personally my opinion is that the Hallett's Cove and Inman Valley beds are undoubtedly to be correlated with those of Bacchus Marsh.)

Question 4. In regard to the contemporaneity of the Permo-Carboniferous Glacial beds in various parts of the Commonwealth, there can, in my opinion, be no question that the Bacchus Marsh and Wynyard Glacial beds were absolutely contemporaneous. They both conformably underlie *Gangamopteris* beds, respectively at Bacchus Marsh *Gangamopteris* Sandstone Quarry, and between Wynyard and Preolenna (in North-Western Tasmania). Even individual tillite beds can, I think, be correlated with one another, in the cases of Bacchus Marsh and Wynyard. The Inman and Hallett's Cove Glacial beds, in spite of the absence of fossils, can, I think, be quite safely considered as contemporaneous with those of Bacchus Marsh and Wynyard. The Lochinvar stage or series of New South Wales, like those of Bacchus Marsh and Wynyard, underlies *Gangamopteris*-bearing strata and graduates downwards conformably, at Seaham and the Paterson area in the Lower Hunter District of New South Wales, into the tuffaceous shales containing *Aneimites* (*Rhacopteris*). In fact C. A. Süssmilch

IV.

Correlation-Table of the Permian, Permo-Carboniferous, and

By Professor T. W. E. David,

Horizon	Tasmania	Victoria	South Australia	Western Australia	New South Wales	Queensland
	Southport Coal Measures					
				Collie Creek Coal Measures	Newcastle Series	Clermont and Tolmie's Coal Measures
Neo-Permian	Mt. Cygnet and Adventure Bay Coal Measures				Dempsey Series	
		Schizoneura Beds Bacchus Marsh			Tomago Series	
	Upper Marine Series of Preolenna, etc.				Upper Marine Series with a well-marked Glacial Horizon 1,500 ft. above its base and a marine boulder bed over 2,000 ft. above the base of the Series	Marine Beds of Clermont and Capella. Glossopteris Beds of Oakey Cr. and St. Mary's on MackenzieRiver Marine Beds of Oakey Cr. and St. Mary's
	Gangamopteris Beds, Mersey and Fingal	Gangamopteris Beds, Bacchus Marsh			Greta and Ashford Coal Measures with Gangamopteris	Dawson River Anthracites
Palæo-Permian or Permo-Carboniferous	Lower Marine Series of Preolenna, Pachydomus and Eurydesma Beds of Maria Island, etc.				Lower Marine Series with Eurydesma cordatum	Gympie Series with marine fossils
	Wynyard Glacial Beds	Glacial Series of Bacchus Marsh Coimodai, etc.	Glacial Series Inman, Hallett's Cove, etc.	Lyons Conglomerate and Irwin River Boulder Bed	Glacial Beds of Lochinvar and Seaham. [Note: Aneimites (Rhacopteris) occurs in basal part of these Beds at Seaham.]	Boulder Beds (?) of Windah on MackenzieRiver
Carboniferous		Avon River Sandstones with Lepidodendron australe. Mansfield Fish Beds. Grampian Sandstones, etc.		Lepidodendron Beds of Kimberley, Limestones of Mt. Marmion Kimberley	Middle, possibly Upper, Carboniferous: Aneimites (Rhacopteris) Beds or Series with Calamites. Very massive Conglomerates. Arkose, Tuffs and Rhyolites. Lower Carboniferous: Lepidodendron volkmannianum Series with L. veltheimianum Ulodendron, etc. Lithostrotion and Syringopora Limestones with Syringothyris	Star Series with Phillipsia, Aneimites, Lepidodendron australe, and Rhynchonella pleurodon. (Possibly the L australe and R. pleurodon Beds are Upper Devonian)
Devonian		Iguana Creek Beds and Tabberabbera Shales (?)		Kimberley Series		Burdekin Limestone (Mid. Devonian)

Carboniferous Rocks of the Southern Hemisphere and India.
C.M.G., D.Sc., F.R.S., etc.

Northern Territory	New Zealand	India	South Africa	South America	Falkland Islands	Antarctica
	Possibly some of the lower non-fossiliferous beds of the Maitai Group belong here (Maitai Group is mostly Trias-Jura)	Upper Productus Limestone; Damuda Stage with Glossopteris, Schizoneura, and Phyllotheca. Raniganj Coalfield; Ironstones Shales; Barakar Sub-stage; Lower Productus Limestone	Middle Beaufort with Dicynodon (?) Lower Beaufort with Glossopteris and Schizoneura and numerous Reptiles. Ecca Beds and Glossopteris, Gangamopteris Schizoneura and Lepidodendron pedroanum. Upper Dwyka Shales with Mesosaurus	Passa dois Series with Lycopodiopsis derbyii and Mesosaurus. Rio Bonito Shales with Glossopteris, Gangamopteris and Lepidodendron pedroanum	Glossopteris and Phyllotheca Beds of Speedwell Islands, &c.	Beacon Sandstone (in part) *i.e.* the Coal Measures with Glossopteris Beardmore Glacier, Granite Harbour, &c. of Ross Region Antarctica
Marine Beds at Port Keats		Lower Productus Limestone of Salt Range				
Thin coaly laminæ with Glossopteris and Gangamopteris Port Keats		Karharbari Coal Measures with Gangamopteris		Gangamopteris obovata Beds		
		Salt Range Marine Beds with Eurydesma	Eurydesma Beds (E. globosum) of S. W. Africa			
		Boulder Beds of Salt Range and Talchir Boulder Beds with Gangamopteris	Dwyka Conglomerates (Glacial Series) Gangamopteris is associated with tillite	Orleans Conglomerates and Rio Nero Boulder Beds in Marine Shales. Sandy Tillites on 3 horizons. Total thickness 2,300 ft.	Glacial Beds underlying Glossopteris Strata	
		Lower part of 'Po Series' with Culm Flora, Aneimites, &c., and Spiti Plant Beds				
		Spiti Shales with Phillipsia and Syringothyris cuspidata	Witteberg Series			
		Muth Quartzites and Limestones. Padaukpin Limestones. Wetwin Shales		**Devonian Marine Series of Lower Amazon Valley**	**Marine Quartzites with Spirifers**	**Beacon S'stones of Granite Harbour with Middle Devonian Fish Remains**

has quite recently discovered a fragment of an *Aneimites* leaflet in a bed of shale actually in, but close to the base of, the Seaham Glacial series.

Now, *Aneimites* is of true Carboniferous age, and may even belong to a Lower Carboniferous (Culm) horizon. At all events it cannot probably be newer than Upper Carboniferous, if as new. While the *Gangamopteris* horizon of the Lower Hunter links up the Lochinvar stage with that of Bacchus Marsh and Wynyard the occurrence of *Aneimites* in the base of the Glacial beds at Seaham in New South Wales suggests either:—(*a*) that in New South Wales the basal part of the beds is of true Carboniferous, possibly Middle or even Lower Carboniferous age, or (*b*) that *Aneimites* in Australia survived into later geological time than it did in Europe. The fact that on the whole it is distinctly above the *Lepidodendron veltheimianum*, *L. volkmannianum*, *Ulodendron*, and *Syringothyris* horizons, as well as much above the *Lithostrotion* and *Syringopora* limestones of the Lower division of Carboniferous rocks in the New England District of New South Wales, suggests that it is perhaps Post-Culm in age in New South Wales. The Glacial beds described by Professor Woolnough ('Proc. Roy. Soc. N.S.W.,' vol. xiv. 1911, pp. 159-168) were certainly formed contemporaneously with those of the Lochinvar-Seaham areas.

In Western Australia the Lyons Conglomerate of the Gascoyne-Minilya-Wooramel areas and the Glacial beds of the Irwin River area are surely contemporaneous with one another. On the Wyndham River in the Gascoyne District thin boulder beds occur with marine Permo-Carboniferous fossils in the matrix and underlie limestones containing *Aulosteges*, *Productus semireticulatus*, *Cleiothyris* (*Athyris*) *macleayana*, &c. (the last in particular is a true Carboniferous type), as recorded by R. Etheridge, jun. *Phillipsia grandis* is also recorded (*cf.* F. Chapman, 'Australasian Fossils,' p. 232) from the Permo-Carboniferous rocks of the Gascoyne district, but its exact horizon in regard to the Glacial beds is not defined. Again, at the Irwin River Glacial horizon, the Glacial beds (in that case 430 feet thick) underlie conformably limestones and ferruginous bluish shales containing *Productus semireticulatus*, *Aulosteges*, *Spirifer musakheylensis*, &c.,—marine forms which suggest a Glacial horizon considerably below that of the Greta Coal Measures (essentially *Gangamopteris* Coal Measures). The Western Australian Permo-Carboniferous Glacial horizon may, therefore, be provisionally correlated with that of Bacchus Marsh, Inman, Wynyard, and Lochinvar.

In Queensland, B. Dunstan has recorded slates of Gympie (Lower Permo-Carboniferous age) at Windah, on the Mackenzie River, to the west of Rockhampton ('Queensland Government Mining Journal,' April 15, 1901). For these boulder beds he suggests a Glacial origin.

W. H. Rands has also recorded small boulders which he considered to be probably of Glacial origin in the Gympie beds at Gympie. (Quoted in 'Geology and Palæontology of Queensland and New Guinea,' by R. L. Jack and R. Etheridge, Jun., p. 77.)

These boulders, mostly not more than one foot in diameter and enclosed in fine shale, may or may not have been transported by ice. The Windah beds are more suggestive of the action of floating ice and

may be tentatively referred to the Lochinvar Glacial horizon of New South Wales. R. L. Jack's discovery of boulders, about two feet in diameter, near the base of the Middle Bowen formation (*op. cit.*, pp. 150-151) does not make it clear whether these supposed ice-rafted boulders occur below the Middle Bowen or are intercalated in them. They are stated to be associated with portions of trunks of coniferous trees, and, as Jack suggests, may have been dropped in heaps from the floating stumps of trees. Probably their horizon is equivalent to that of the Branxton beds of the Upper Marine series of New South Wales.

If this correlation is correct the Bowen boulders are on a higher horizon than that of Bacchus Marsh, &c. Certainly at Branxton and West Maitland in New South Wales large boulders, in some cases from one to three tons in weight and occasionally well glaciated, are found on a horizon about six thousand feet above that of the Lochinvar Glacial horizon; and in this thickness of 6,000 feet of strata, chiefly marine, are intercalated the Greta Coal Measures containing in the aggregate from 20 to 40 feet of coal.

Obviously, therefore, in the Lower Hunter area there are two distinct Glacial horizons, the Upper about a third of the way up above the base of the Upper Marine series and the Lower at the very base of the Lower Marine series. With the exception, however, of this case at Branxton and of the Irwin River, and of, perhaps, the Middle Bowen boulders, all the main Permo-Carboniferous horizons in Australia and Tasmania appear to lie at the very base of the Permo-Carboniferous system and can be safely correlated with one another.

Question 5. In regard to the vast question raised in the Table of Correlation of the Permian, Permo-Carboniferous, and Carboniferous Rocks, of the Southern Hemisphere, the following notes are suggested:—

Under table for New South Wales *re* '*Rhacopteris*-bearing series,' as Arber now refers *Rhacopteris* to *Aneimites* this series might be termed: *Aneimites* (*Rhacopteris*)-bearing series.

I am inclined to the expression *Palæo-Permian*, not as an exact synonym for *Permo-Carboniferous*, but as meaning something older than the Neo-Dyas (Zechstein) horizon, and not only as old as the Palæo-Dyas (Rothliegendes) but taking in some infra-Rothliegendes rocks which at the same time are newer than the Pennsylvanian of the Upper Carboniferous of North America.

The term Permo-Carboniferous, on the other hand, while it takes in infra-Rothliegendes rocks should include some rocks which would be considered to be of Upper Carboniferous age. Provisionally it seems to me that we may adopt the following conclusions:—

(1) That if we may interpret the phenomena of Palæozoic glaciations by those of Pleistocene, the glaciations of the Northern and Southern Hemispheres were so nearly, if not absolutely, synchronous, that they may be referred to the same series of rocks in either hemisphere.

(2) If this be admitted, then the Squantum tillite (admitted by Professor Coleman, W. M. Davis, &c., to be undoubtedly a tillite)

and which is *apparently* statigraphically just above the Narragansett Bay Coalfields, is homotaxial with the Bacchus Marsh and Wynyard Glacial beds.

(3) The Narragansett Bay Coalfields are of Pennsylvanian age, which extends to about the top of Carboniferous time.

(4) Though unfortunately the stratigraphy of the Squantum tillite is yet somewhat in doubt, it is very improbable that it can belong to the Mississippian (Lower Carboniferous). The number (288 species) of Sharks, and their geographical distribution, as well as the geographical range of the reef-forming coral isotherms show that a warm climate prevailed universally at that time. The sharks are still numerous (55 species) in Pennsylvanian (Middle and Upper Carboniferous time) and the great size and abundance of insects in the Pennsylvanian Coalfields confirms the evidence of the sharks as to the Upper Carboniferous climate in North America having been mild.

(5) The minerals found in rocks of Zechstein age at Stassfurt such as Langbeinite, Loweite, Vanthoffite, Kieserite and Sylvine also imply a warm or at least a mild climate for the Neo-Permian,[1] the evidence of reef-forming corals being also in accord.

(6) Unless the Squantum tillite is of Cambrian or Pre-Cambrian age (an unlikely hypothesis), it must, as it is certainly not newer than Palæozoic, belong probably to a cold epoch intervening between the close of Pennsylvanian time and the commencement of Zechstein time.

(7) According to Amalitzky, the whole of the Dwina system of Russia, which contains an abundance of *Glossopteris* and *Gangamopteris*, is wholly of Zechstein age, marine strata with *Schizodus* and *Bakewellia* underlying the whole system, so that even *Gangamopteris* in Russia ascends into the Upper Permian, but no higher as far as is known, for these *Glossopteris-Gangamopteris* beds are capped by marine strata containing the characteristic Zechstein fossils, *Syncladia* and *Acanthocladia*. Thus in Russia *Gangamopteris*, so much associated in the Southern Hemisphere with the Greta Coal Measures, is by no means associated with a European Carboniferous marine fauna, but on the other hand with an Upper Permian fauna. (Time, of course, must be allowed for the migration of the *Glossopteris-Gangamopteris* flora north-westwards from India to where the Dwina system is developed in the Muscovian area of Russia, but a whole period of geological time would scarcely be needed for such a migration.)

(8) While unfortunately no development of the so-called Permo-Carboniferous Glacial horizon has been found beneath the Dwina system, it has been stated that in Westphalia the upper surface of the Westphalian Coal-measure rocks is striated and capped by a typical ground-moraine. Van Waterschoot Van der Gracht has republished G. Muller's original figures of some of these striated pebbles, which he states cannot be confounded with pebbles showing pseudo-striæ due

[1] *Neues Jahr.* 5 Feb. 1910, *für Min. Geol. und Pal.* XXIX. Beilage Band, Erstes Heft. E. Philippi, *Ueber eine palaeoklimatische Probleme.*

to tectonic movements. At the same time the Government Geologist of the Netherlands admits that the scene of this discovery is in a much-faulted region, so that the evidence cannot be considered conclusive.

(9) While the above considerations suggest a wholly post-Pennsylvanian and therefore Post-Carboniferous age for all our Australasian strata from the base of the Bacchus Marsh beds to the topmost of our *Glossopteris* flora beds, the survival in the West-Australian Permo-Carboniferous beds of *Productus semireticulatus*, *Cleiothyris macleayana*, &c., and the occurrence at Seaham in New South Wales of *Aneimites* in the basal portion of the Lochinvar Glacial series suggests an age as old at least as Upper Carboniferous, but in this regard the words of Diener are worth quoting.[2]

On p. 144, Diener says: 'Bearing in mind the gradual passage from an Upper Carboniferous to a Permian fauna through the intermediate group of rocks, the question to be answered is which consideration is of the greater importance in defining the boundary between the two systems, the appearance of a new group of cephalopods which become of an unparalleled stratigraphical value in Mesozoic times, or the presence of a belated fauna composed of forms which are generally not well adapted for the characterisation of narrowly limited horizons?'

In my opinion, all the strata from the base of the Bacchus Marsh beds to the top of the Newcastle series of New South Wales will yet prove to be post-Pennsylvanian, and therefore post-Carboniferous in the European use of the term Carboniferous, and yet the lower part of the Southern Hemisphere Permo-Carboniferous strata may be infra-Rothliegendes.

Nevertheless, the term Permo-Carboniferous had better be retained for the present.

Question 7. Discordance of junction between Carboniferous and Permo-Carboniferous in Southern Hemisphere.

(A) *Discordance.*

(1) At Ashford, near Inverell, in New South Wales, there is an immense unconformity (almost a right angle between the directions of bedding) between the *Gangamopteris* (Greta) Coal Measures and the *Productus semireticulatus* limestone series.

(2) At Pokolbin, near Cessnock, in the Maitland district of New South Wales, there is a marked unconformity with strong overlap of the Lower Marine series on to the *Aneimites* series.

(3) In the Nandewar Ranges, New South Wales, there is a strong unconformity between the *Glossopteris* Coal Measures of Newcastle (?) age and the Carboniferous strata.

[2] *Amer. Journ. of Sci.* vol. xxii. Aug. 1906, 'The Russian Carboniferous and Permian compared with those of India and America: a Review and Discussion,' by Charles Schuchert.

(B) *Accordance.*

At Seaham, in the valley of the Williams River above Raymond Terrace in New South Wales, there appears to be a complete accordance between the *Aneimites* beds and the Lochinvar beds of the Lower Marine Permo-Carboniferous series. Mr. W. N. Benson records a similar accordance at Burindi in the New England district, New South Wales.

V.

Remarks on the Hon. Secretary's Communication by Mr. WALTER HOWCHIN, *F.G.S., University of Adelaide.*

1. Where beds, in different localities, exhibit a close resemblance in their lithological and faunal features, suggesting contemporaneity, I think a common name is desirable. Local names, such as 'Bowen' and 'Gympie,' could be used simply in a geographical sense subordinate to some common term. (See under par. 3.) I should make an exception, however, where, in the same geological system, beds of strongly contrasted features arising from differences of origin occur—as, for example, in a series laid down under conditions of land ice.

2. It seems desirable that a comprehensive name should be used to indicate homotaxial affinities. The homotaxy may be, to some extent, imperfect, as might be expected in the case of areas widely separated—but the advantage of having a term that conveys the idea of chronological position is very great, especially to students in other countries. I prefer Permo-Carboniferous to Carbo-Permian, in that it is already in common use. Whether 'Permo-Carboniferous' or 'Permian' should be adopted must be determined, I think, on the palæontological evidence.

3. Where a geological system includes very distinct, and even contrasted, features in relation to the origin and modes of deposition of its several members, it seems the proper thing to use separate terms to distinguish the respective sections. It will be, of course, the type district that supplies the name in each case. Thus, in the Permo-Carboniferous (or Permian) system of Australia we have two entirely distinct sets of beds, a marine and lacustrine series, which has its greatest development in New South Wales; and, in addition, a thick series that has resulted from land glaciation in South Australia and Victoria. These are so distinctive that, I think, they should be separately recognised in the classification—for example,

Permo-Carboniferous system. { *The Hunterian series.* / *The Inman series.*

Some of the members of the British Association who visited the Permo-Carboniferous Glacial fields in South Australia suggested that some distinctive name for these beds should be adopted in Australia, as had been done in South Africa (Dwyka) and in India (Talchir). Professor W. M. Davis also wrote to me to the same effect after he

had left Adelaide, and suggested that as it was in the Inman that the first evidences of glaciation were recognised in Australia, perhaps some native name appropriate to the locality could be selected for this purpose. With the assistance of Dr. Stirling I have paid some attention to the matter in examining the native vocabularies of the district. The tribe which occupied the valley of the Inman and adjacent coast was the Ramin'yere (accent on second syllable, and the following four letters in two syllables=ye-re). The name Inman is euphonious, and was used by Selwyn, and has the advantage of being on the map. Which of these two names should be selected for the purpose is a question that the Committee might consider.

4. The glacial beds of South Australia, now under consideration, can only be placed in chronological relationship with other glacial beds of Australia by inference. The grounds of such a reference are as follows:—

(*a*) *Stratigraphical evidence.*—In all cases, and they are very numerous, where the base of the glacial beds come under observation they rest on a Cambrian floor; and in several localities where the upper limits of these beds can be seen, they exhibit an eroded surface covered with the lowest members of the marine Tertiary. The stratigraphical limits are therefore post-Cambrian and pre-Tertiary.

(*b*) *Lithological evidence.*—The general aspect of the beds, their degree of induration, as well as other stratigraphical features, show a close likeness to the Bacchus Marsh series.

(*c*) *Evidence by exclusion.*—There is no known Glacial period that occurred in Australia that these beds can be reasonably correlated with other than the Permo-Carboniferous. It is scarcely likely that a glaciation on so large a scale as occurred in the Inman Valley district should leave in Australia but one surviving evidence. Yet, although the circumstantial evidence is very strong, it cannot be regarded as demonstrated.

With respect to the remaining questions, I have not had sufficient experience to warrant my expressing an opinion.

VI.

Remarks on the Hon. Secretary's Communication by Professor W. G. Woolnough, *D.Sc., University of Western Australia.*

Questions 1, 2, 3. I prefer a general Australian name for the whole formation, with locally named subdivisions. For the general name, I think Hunterian is to be chosen, (*i*) because of priority of use, (*ii*) because of the extent and perfection of development of the beds in that district, (*iii*) because the relationships of the different members have been more completely studied and determined there than elsewhere. I oppose strenuously the use of any such general term as Permo-Carboniferous, Carbo-Permian, or Permian, because I am by no means convinced that the beds in question are strictly homotaxial, even, with beds of those names in different parts of the world. The

VII.

Modifications by

On the Correlation-Table (II.) *of Permian, Permo-Carboniferous, and*

Horizon	New South Wales	Victoria	Queensland	West Australia	South Australia and Northern Territory
Permian		Schizoneura Sandstones of Bacchus Marsh ?	Upper Bowen Series ?	? Miningenew Marine Beds	
Permo-Carboniferous	Newcastle Series with Glossopteris		↓	Collie River Coal Series with Gangamopteris	
	Dempsey Series			In Irwin R. the Glacials Marine Beds and Coal Measures form a continuous ascending series	
	East Maitland or Tomago Series			In sandstones immediately overlying a coal seam are numerous glacially 'dumped' boulders.	
	Upper Marine Series with Glacial Boulders			The base of the series is not seen	
	Greta Series with Gangamopteris	Gangamopteris Sandstone of Bacchus Marsh	Lower Bowen and Dawson Coal Series	Gascoyne Worramel and Minilya Series with Lyons Conglom. at base	Victoria River and Arnhem Land Series (N. Terr.) with Glossopteris ?
	Lower Marine Series with Glacial Conglomerate (*See below* †)	Tillites, &c., of Bacchus Marsh Derrinal, &c.	Gympie Series with Gangamopteris		Tillites, &c., of Hallett's Cove, Inman Valley, &c.
Carboniferous	Rhacopteris-bearing Series	Avon River Mansfield and Grampian Sandstones ? with Lepidodendron australe	Star Series with Lepidodendron australe	Kimberley Series with Lepidodendron ?	Lepidodendron Beds of MacArthur R. ?
	Lepidodendrum volkheimianum-bearing Series		↓		
Upper Devonian ?	Mt. Lambie Series	Iguana Creek Beds ? with Cordaites			Elvire R. Beds ?

Note.—In Irwin River district of Western Australia there appears to be a lateritized land-surface

† Sub-glacial Beds with a Gympie

Professor W. G. Woolnough.

Carboniferous Rocks of the Southern Hemisphere and of India by Professor E. W. Skeats.

Tasmania	New Zealand	South Africa	South America	Antarctica	India
Knocklofty Series with Vertebraria indica?	Wairoa Series (Park)? Kaihiki Series (Park)?	Lower Beaufort with Pareiasaurus and Glossopteris	Schizodus Series of Brazil with Mesosaurus	Beacon Sandstone? ↑	Panchet Series? ↑
	Aorangi Series (Park)? ↑	↑	↑		
	Maitai Series? (in part)	?			?
Sandy Bay Series				Beacon Sandstone?	Damuda Series
Mersey Series	↓	Ecca and Kimberley Series with Mesosaurus ↓	Santa Catharina Series of Brazil and Argentine with Orleans Glacial Conglomerate at base		
Glacial Series of Wynyard, Eaglehawk Neck, &c.		Tillites, &c., of Dwyka Series		?	Talchir Series with Glacial Conglomerate at base
	↓	↑ Witteberg Series ↓			
		Bokkeveld Series?			

separating Coal Measures from Mesozoic. There is a slight, but decided unconformity. (W.G.W.

facies occur on the Macleay River.

adoption of any distinctive age-term, at the present time, is undesirable, as future investigations may lead to more than one readjustment of our ideas, with the consequent inconvenience of alteration of nomenclature. All these difficulties can be overcome by the agnostic attitude implied by the employment of a local name. I do not think all palæontologists have taken into account, to a sufficient extent, our great distance from other parts of the world, and the absolute certainty of mingling of different streams of biological migration, which here bring together apparently contradictory assemblages of organisms.

4. I am inclined to believe that the main epoch of glaciation was that represented by the Lochinvar Glacials of the Hunter River. I think that cold conditions continued throughout the period, with locally extended distribution from time to time, probably governed very largely by geographic accidents. On the Irwin River, for instance, we have distinct evidences of floating ice in the sandstones immediately above the coal seam, *i.e.*, probably in the equivalents of the Greta series. The vast bulk and apparent continuity of the Glacial beds in South Australia and Victoria, I suggest, is due to the fact that these were essentially land areas at the period, and continued to be glaciated even at those times when local retreat of the ice cap prevented the wide distribution of glacial materials by floating ice. Local glaciers, which suffered from shrinkage to a less extent than others, may account for the apparent differences in age of the minor Glacial beds in different States. The recognition that on the Manning and Macleay Rivers of New South Wales the main glaciation is Lower Marine extends the geographical limits of the ice-action of that particular phase in Eastern Australia, while the beautiful sections of the Irwin River district in Western Australia are, at least, not unfavourable to the assumption of absolute contemporaneity. I am therefore inclined to answer yes to question 4.

Question 5. With the slight modifications suggested on the accompanying table (VII.), I agree with the correlation. I am of opinion that for the reasons stated in my answer to 1, 2, 3—namely, the mingling of migration streams—biological comparisons are less trustworthy than are the features of a great climatic revolution, in the correlation of beds in widely separated regions.

Question 6. I am unable to answer definitely.

Question 7. My paper, 'Preliminary Note on the Geology of the Kempsey District' ('Journ. and Proc. Roy. Soc., N.S.W.,' vol. xiv. 1911, pp. 159-168), indicates the strong probability of conformable passage from Carboniferous to Permo-Carboniferous in the central coastal area of New South Wales.

Question 8. I cannot express a very definite opinion. In August next I hope to examine the Irwin River area again with some care. I shall bear this question in mind then.

VIII.

Discussion by the Hon. Secretary, Professor SKEATS, *of the points raised by him, after reading the replies of* Professor DAVID, Professor WOOLNOUGH, *and* Mr. HOWCHIN.

1. A single common name with local names used in a purely geographical sense is advisable. For example, in Victoria, among rocks grouped as Permo-Carboniferous, are the Bacchus Marsh series, the Knowsley series, the Loddon Valley series, the Coleraine series, &c. Only at Bacchus Marsh is there definite palæontological and stratigraphical evidence of the age of the rocks, and it therefore is probably inadvisable to include them all under one local name and thereby tacitly assert contemporaneity between them, although all are probably Permo-Carboniferous. Professor David is, I think, incorrect in claiming that the Bowen series of Queensland includes more than the Bacchus Marsh series. The latter series appears to range continuously and conformably from the basal Glacial series through *Gangamopteris*-bearing sandstones up to beds, probably of Triassic affinities, containing *Schizoneura* and *Tæniopteris Sweeti* (McCoy).

2. The term Permo-Carboniferous is already firmly established, and I know no good reasons for changing it, especially as Carboniferous marine types in Western Australia and Carboniferous land plants (*Aneimites* or *Rhacopteris*) at Seaham, in New South Wales, are included in the series which otherwise, on the bulk of the palæontological evidence, might apparently have been called Permian.

3. It seems inadvisable to apply a single local name to all the Australian occurrences of presumably Permo-Carboniferous rocks. Hunterian is a suitable name for the very complete marine and lacustrine development in New South Wales. The Victorian sequence is, however, very distinct, being at Bacchus Marsh mainly fluvio-glacial, with several included tillites derived from land ice, while in other Victorian localities the tillite is alone represented or is predominant. In South Australia the Inman series, as it might suitably be called, consists largely of tillite. As there are two or more glacial episodes known in New South Wales and Victoria, and as in South Australia we have no definite stratigraphical and palæontological evidence of the age of the tillite, the giving of a single local name to the tillite (comparable with the term Dwyka, in South Africa) seems premature.

4. It cannot yet be proved that the prominent Glacial horizon at the base of the series is everywhere in Australia contemporaneous. In New South Wales, Victoria, Queensland, and Western Australia Glacial conditions recur higher in the series. In South Australia, as has been stated, no definite evidence of the age of the Glacial series has been obtained. Nevertheless, on the grounds put forward by Mr. Howchin, the prominent Glacial till is probably everywhere on approximately the same horizon.

5. It is believed that the correlation suggested (by E. W. Skeats) broadly expresses the facts of the relationships of the rocks considered

in the Southern Hemisphere. Professor David's more detailed correlation is, however, accepted apart from minor points. Carboniferous types of fossils have been recorded from part of the Maitai series of New Zealand. The Schizoneura beds of Bacchus Marsh apparently range up into the Trias, and conformably down into the *Gangamopteris* sandstones. It is questionable whether the term Permian in the original correlation and Neo- and Palæo-Permian in Professor David's correlation are required. If we define the upper limit of the Permo-Carboniferous series as limited by the occurrence of *Glossopteris*, most of the rocks included in the Neo-Permian of Professor David's correlation are Permo-Carboniferous. Professor Woolnough's additions to the correlation are agreed to. Owing to wide geographical separation, as Professor Woolnough claims, differences in the assemblage of fossils in beds of the same age are to be expected, and the evidence of a climatic revolution, such as a Glacial episode, probably provides a better basis for correlation. We require to be certain, however, that over a wide area similar conditions as to height above sea-level and relations of land and sea obtained, and that no slow progressive shift in the areas of maximum glaciation occurred. We have not yet such complete evidence. Where, however, as in some areas, the facts of palæontology and of climatic revolution are associated together, the probabilities of the several occurrences in different areas being contemporaneous is greatly increased.

6. Conformable sequence in Victoria and South Africa. Other areas, relations are not known.

7. Conformable in south of South Africa, unconformable in north part of South Africa and in parts of New South Wales. The relations are unknown in Victoria, as the two series have not been observed in contact.

8. Permo-Carboniferous must be taken to include the whole of the Permian, and its upper limit in the Southern Hemisphere is the upper limit of the *Glossopteris* flora. At Bacchus Marsh the sandstones with *Schizoneura* and *Tæniopteris sweeti (McCoy)* suggest a conformable passage up into the Trias. This appears also to hold in South Africa, in India, and in parts of New South Wales. In other parts of New South Wales a slight discordance occurs.

IX.

Summary of Views of the Australian Members of Committee. By the Hon. Secretary, Professor E. W. Skeats.

1. There is general agreement that a single name for all the Australian Permo-Carboniferous rocks should be adopted while retaining local names already in use, in a geographical sense.

2 and 3. With respect to the questions as to whether the single name should be general or local, *Professor David* gives reasons for the retention of the term Permo-Carboniferous as the general name, while claiming that if a single local name be adopted the term Hunterian should be used on the grounds of priority and the complete development of the

Permo-Carboniferous to Carbo-Permian, but suggests that the term Hunterian series might be used for all the marine and lacustrine developments in Australia, and that the term Inman series should be used for the products of land glaciation, while, if an aboriginal name for the latter series be thought desirable, the term Ramin'yere is appropriate. *Professor Woolnough* objects to the use of the term Permo-Carboniferous on the grounds of lack of proof of homotaxial relations with similar rocks in other parts of the world. He prefers a general Australian name, and says Hunterian should be chosen for reasons stated above by Professor David. *Professor Skeats* maintains that Permo-Carboniferous is an appropriate general name already in wide use and expressing the admixture of certain Carboniferous types with a Permian fauna and flora. He does not agree to the use of a single Australian name, as the special developments vary in different areas—in New South Wales being mainly marine and lacustrine, in Victoria mainly fluvio-glacial with several tillites, and in South Australia tillite, the product of land glaciation, is largely represented. He thinks it is premature to suggest a local Australian name (comparable with Dwyka in South Africa) to indicate the dominant tillite horizon, since in some States two or more horizons are known, and in South Australia the horizon is inferred and not proved.

4. In respect to the question whether the prominent glacial conglomerate is always on the same geological horizon in Australia, there is general agreement that the probabilities are in favour of this view, while it can in most cases not be proved but only inferred. *Professor David* points out that the Glacial series of Wynyard in Tasmania, of Bacchus Marsh in Victoria, and of Lochinvar in New South Wales, can be correlated; that in Western Australia the Glacials contain Permo-Carboniferous fossils and underlie rocks containing some Carboniferous types. *Mr. Howchin* maintains the inference that the South Australian Glacial series are of the same age as elsewhere in Australia, on lithological similarities, and because there is no other known Glacial horizon with which they can be correlated. *Professor Woolnough* believes that the lower main Glacial phase is probably everywhere on the same geological horizon, and that where differences of age are indicated in Glacial beds in higher parts of the series they may be the effects of local glaciations. *Professor Skeats* believes that the lower prominent Glacial series is probably everywhere contemporaneous, though in several areas this cannot be proved, but may be inferred for the reasons suggested by Mr. Howchin.

5. In respect to the question as to whether the correlation of Permo-Carboniferous rocks in different parts of the world suggested in the correlation prepared by Professor Skeats is probably correct, *Professor David* agrees generally with the correlation, but amplifies it. He quotes evidence given by Amalitzky that in Russia the *Gangamopteris* flora is associated with marine Permian types, while the Squantum tillite of America appears to be, but has not yet been proved to be, post-Upper Carboniferous in age. *Mr. Howchin* has not discussed this or the later questions of correlation. *Professor Woolnough* agrees gener-

ally with the correlation, suggests a few additions, and claims that correlation by evidence of a climatic revolution is probably safer than by evidence of fossils where widely separated areas are concerned. *Professor Skeats* accepts Professor David's and Professor Woolnough's additions and modifications to the correlation with certain minor reservations as to the probable horizon of the lower part of the Maitai series in New Zealand, and of the upper part of the Bacchus Marsh series as expressed in Professor David's table. He agrees with Professor Woolnough's remarks about correlation by evidence of a climatic revolution, provided that in the case of the formation of a Glacial series no marked inequalities of land level, or of the relations of land and sea, or evidence of slow migration of the areas of maximum glaciation, are involved. Where palæontological and lithological evidence of Glacial deposits are combined, the probabilities of the series in different areas being contemporaneous are much increased.

6. Are relations between Devonian and Carboniferous rocks in the Southern Hemisphere everywhere conformable? No replies have been received. *Professor Skeats* maintains the existence of a conformable sequence in Victoria and in South Africa, but does not know the relations in other areas.

7. In respect to the question as to the areas of accordance and of discordance between Carboniferous and Permo-Carboniferous rocks, *Professor David* points to discordance at Ashford and Pokolbin in New South Wales, and at the Nandewar Ranges (between the Newcastle series and the Carboniferous); to accordance at Seaham and Burindi in New South Wales. *Professor Woolnough* refers to accordance in the central coastal areas of New South Wales, while *Professor Skeats* refers to accordance in the south of South Africa and discordance in the northern parts of South Africa and in parts of New South Wales. In Victoria the two series do not come in contact with each other so far as is known.

8. In respect to the question as to the upper limit of the Permo-Carboniferous and its separation, if any, from the Permian, *Professor David* and *Professor Skeats* agree that the upper limit is the upper limit of the *Glossopteris* flora,[3] while *Professor Skeats* claims that since rocks with the *Glossopteris* flora usually pass gradually into Mesozoic rocks, the Permo-Carboniferous series must be taken to include the whole of the Permian series.

NOTE.—While *Mr. W. S. Dun* has not directly contributed to this discussion, it is understood that he consulted with Professor David and agrees generally with his conclusions.

[3] This view is expressed with reference to the Southern Hemisphere only, since *Glossopteris* has been recorded from the Rhætic series in Tonkin, South China, and Mexico.

The Question of Fatigue from the Economic Standpoint.—Interim Report of the Committee, consisting of Professor J. H. MUIRHEAD (*Chairman*), Miss B. L. HUTCHINS (*Secretary*), Mr. P. SARGANT FLORENCE (*Organising Secretary*), Miss A. M. ANDERSON, Professor BAINBRIDGE, Mr. E. CADBURY, Professor S. J. CHAPMAN, Professor STANLEY KENT, Dr. MAITLAND, Miss M. C. MATHESON, Mrs. MEREDITH, Dr. C. S. MYERS, Mr. C. K. OGDEN, Mr. J. W. RAMSBOTTOM, *and* Dr. J. JENKINS ROBB.

THE following Report has been drawn up by Mr. P. Sargant Florence. Besides this and in a measure incorporated in it are memoranda presented to the Committee by Mr. J. W. Ramsbottom, Dr. Brown, Mr. A. Greenwood, Professor Bainbridge, and Miss B. L. Hutchins, and a subsidiary psychological investigation by Mr. C. K. Ogden. The latter includes a translation of Max Weber's 'Zur Psychophysik der industriellen Arbeit' (see Index D8) and a complete bibliography of the Psychology of Fatigue.

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Section 1.—*The Nature and Causes of Fatigue.*

If we define fatigue in general as a 'diminution of the capacity for work which follows excess of work or lack of rest, and which is recognised on the subjective side by a characteristic malaise,' we at one and the same time put forward its most familiar symptom and its main external cause.

This 'subjective sensation of malaise' is found, according to Dr. McDougall's address to the British Association in 1908, as a local sensation of fatigue particularly in the muscles, as a general feeling of tiredness or limpness, and also as the experience of sleepiness. But such sensations are no more than symptoms of the diminution of working-capacity and not always even that. As Dr. Rivers has stated: 'A distinction must be made between the sense of fatigue—the sensations which supervene during the performance of work, and the lowered capacity for work executed. These conditions, which may be spoken of as subjective and objective fatigue respectively, do not always run parallel courses. In the performance of mental work especially, decided sensations of fatigue may be experienced when the objective record shows that increasing and not decreasing amounts of work are being done; and there may be complete absence of any sensations of fatigue when the objective record shows that the work is falling off in quantity, or quality, or in both.' This insistence on the distinction between subjective and objective fatigue, however, does not imply that the one has no influence on the other. As Weber points out (see Index of Documents D8), 'This psychically conditioned fatigue is by no means without its influence on working capacity . . . and in the long run it can undoubtedly cause an unfavourable general disposition which will ultimately find a physical expression.'

If excess of work or lack of rest figures in our definition as the antecedent to fatigue it must not make us overlook the physiological *modus operandi* of fatigue as distinguished from those quite external causes. During the last twenty years it has been found, in fact, that muscular fatigue is caused by the accumulation of the poisonous products of activity and the exhaustion or diminished supply of the substances necessary for the continuance of activity, 'and,' wrote Professor Lee in 1910, 'there is every reason to believe that the main principles of muscular fatigue are demonstrable in the other tissues and organs of the body—that in them also fatigue is characterised, physically, by a diminution of working power and, chemically, by both the destruction of energy-yielding substances and the appearance of toxic metabolic products.' But, as Dr. Rivers has pointed out, 'however satisfactory these (physiological) definitions may be ideally, their application is wholly impracticable in the present state of our knowledge, even in the present case of the fatigue of isolated muscle and still more so in the case of general bodily fatigue or of mental fatigue.'

In studying fatigue from the economic standpoint it is of course the objective diminution of working capacity and the external causes found in industry that will be the prime consideration. Subjective fatigue will be of importance just so far as it influences objective fatigue. Physiological or 'internal' phenomena will gain importance as inter-

mediate stages between external economic causes and external economic effects. Viewing the subject, then, objectively and externally, work and rest may be regarded as two forces affecting the organism oppositely, and alternately producing by excess of one or other fatigue and recovery. If work or lack of rest should so far gain a permanent supremacy as to preclude all chance of recovery, then we may speak of chronic or accumulated fatigue, but in general we shall regard simple 'fatigue' as the result of the work that preceded it and dating since the last rest, daily, weekly, or yearly.

It is this 'duration of work' previous to any point of time that will in our conclusion be the main factor correlated to the degree of fatigue at that given time.

As a preliminary to that, however, we must observe that there are many other factors influencing the degree to which fatigue may occur in any particular case. A strong individual on easy work and in pleasant surroundings may after five hours' work be much less fatigued than is a weakling after three hours on hard work and in noxious surroundings.

From the economic standpoint and with the definition of fatigue we have adopted, however, these other factors will appear rather as '*predisposing conditions*' enabling excess of work or lack of rest to take effect to different degrees than as 'active' determining causes. Attempts to enumerate all the conditions that are thus likely to influence fatigue have been made by Max Weber, Emil Roth, and other psysiologists, and below we have classified their combined inventories, though it is only the particular influences that seemed both determinant and determinable that have been separately studied in Section V (B).

1. *The Nature of the Work.*

   See Section I.A.

2. *The Surroundings or Environment of the Work.*

   (*a*) Conditions of Factory Hygiene. See Section I.B.

   Temperature } Ventilation.
   Humidity }
   Light (Suitability and Cheerfulness).
   Room.
   Noise (Amount and Regularity).
   Smell.

   (*b*) Factory Organisation.

   A. The '*Incentive*' to Speed or Quality.

   1. Type of Payment:
      By a Profit (a 'Surplus').
      By a Fixed Wage: Rate or Bonus.
         Time Basis.
         Piece Basis.
   2. Honour, Sporting Instincts, &c.
   3. Interest in the Work itself.

B. *Grouping and Subdivision of Labour.*

(*c*) Economic Organisation. (Weber—Index D8.)
Cycles of Prosperity.
Relationship to Work (Cash nexus, Hobby, &c).

3. *The Nature of the Worker.*
Age.
Sex.
Skill and Training.
Opinions (Weber).

4. *The Habits of the Worker.*
1. Sleep: length and times.
2. Nutrition: nature and times. Drinking of Alcohol.
3. Clothing (*e.g.*, its tightness—Roth Index C1).
4. Sexual Relations (Weber).
5. Recreation—especially Sundays.
6. By-occupations.
7. Getting to and from home.

The chain of causation can of course be followed further back. Light and temperature are determined by the time of day or night, temperature and humidity by the season, the climate, and the weather during which the work is proceeding; the opinions, skill and habits of the worker by his social environment, the religion, militarism, trade-unionism around him and the education, especially technical, through which he has passed. But these meteorological and social conditions form the background and need not be more than suggested.

SECTION I.A. *The Nature of the Work.*

The factor of 'nature of work' would in any case require detailed study where fatigue is being viewed from the economic standpoint; but such a study is particularly necessary owing to the confusion of thought and the inconvenience of the terms used of the various characteristics of work affecting the worker. To give only one instance: 'monotonous' is sometimes applied to some objective quality in the work itself, sometimes to the feeling evoked in the worker. Indeed, we shall have to keep separated in our minds three distinct sets of notions: the state and feelings of the worker; certain definite characteristics of the work that alone or together evoke such affections; and the sort of occupations in which such characteristics are usually found.

Now the work of most people can be analysed more or less into a series of separate but *similar* operations, each resulting in some 'output' or service; and each separate operation may in turn be more or less analysed, as Efficiency Engineers have done in 'Motion Studies,' into the different actions (movements and postures, muscular or nervous) that it involves. With this conception in mind we shall be able to estimate more exactly the important 'evocative' characteristics of different sorts of occupations, by putting to each the following questions:

(*a*) What does the operation consist in? what are the separate actions involved?

(*b*) How do the actions fit together into the whole operation, *i.e.*, how 'complex' is the operation?
(*c*) How far are the acts similar in each recurrence of the whole operation, *i.e.*, how uniform is the occupation?
(*d*) How frequently does each operation recur? (The *frequency* is measurable by the average output per hour or per day.)
(*e*) How periodic or regular is the frequency of recurrence of each operation? (The *regularity* is measurable by the mean deviation from the average output per hour or day.)

According to the characteristics elicited by the above questionnaire may be classified the different occupations or crafts involved in industry and some estimate formed of what affections are evoked in the workman by each of such classes of crafts. We shall of course concentrate particularly on such as may be presumed to involve or lead to fatigue.

(*a*) The actions (movements and postures, mental states, &c.) involved in different processes affect the psycho-physique either muscularly or nervously.

'Finicky' work like tying or wrapping up packets or assembling small parts tires the muscles of the hand; packing *bulky* goods into cases or lifting and carrying heavy weights and standing up to work generally tire the central muscles, and illustrations of such muscular overstrain were given by Miss Anderson, the principal Lady Inspector of Factories before the Departmental Committee on Physical Deterioration, 1904, 'where enormously heavy weights were carried by young persons and by women in food-preserving works, bleach and dye works, glass, earthenware and china works, and various metal trades.'

These examples of muscular work become a 'strain' generally because the tax they impose on the body is concentrated or 'focussed' on one particular part; a part whose structure was evolved only to meet the calls of every-day life. This characteristic of '*concentrativeness*' is also obviously involved in all activities calling upon the central nervous system.

Now, such activities of the central nervous system as attending, controlling the muscles, making judgments, remembering and perceiving (sensing and reacting) are activities often exercised in modern industry. Soldering, mending, and most skilled trades, for instance, exercise a judgment of 'quality' in the sense of a comparison with a standard kept in memory. Pasting on labels or cutting articles accurately to shape involves not merely 'sensitivity' of the eyes, but the 'judgment of distance' and a control over muscles, and inserting articles in revolving slots like the paper in a rotary litho machine involves a 'judgment of time.' There is also perhaps a 'sense or judgment of amounts' which is involved where, as in the Stogey Industry (Butler, 'Women and the Trades,' page 85), 'emphasis is placed on close cutting,' and to avoid wasting an unnecessary amount of leaf the rate of pay is more the more cigars are got out of the raw material. Piecing up the threads of cotton in spinning, and all machine-minding, whether it be the work of the machine or the

machine itself that requires attendance, involve the activity of attention for a 'cue' difficult to perceive, and a quick reaction to the cue when it occurs.

Certain portions of a whole operation often do not consist in action so much as in passive rests, 'waiting for the material to set' perhaps. This 'non-persistence' is a characteristic here conditioned by the very nature of the work, and in so far unavoidable even by the most 'efficient' of Efficiency Engineers. For different departments of the iron and steel making process figures were collected in the U.S. Report of the Conditions of Employment in the Iron and Steel Industry (Senate Doc. 110, 62nd Congress, 1st Session, vol. iii., page 345) to show 'the percentage of active work to idle; the actual time being measured by stop-watch to the one-tenth of a minute for an average of four or five days.' It is explained that 'active' means essentially 'that the employee was engaged during the time shown in actually performing some particular function and not simply waiting for the completion of some process or for his fellow-worker to finish some particular job. Such time as this if it lasted more than a minute or two would be included under the head of idle.'

Since we give in full the daily distribution of Iron and Steel Accidents (Table X.) and of the output of Bessemer Converters (Table VIII.) we will reproduce here as an example this table of active time and its percentage of the whole time, which must to a large extent have conditioned the two 'daily distributions,' cautioning the reader to the effect that these are American conditions differing very much from English. Americans generally work a longer day, but use more machinery. (See notes at foot of Tables.)

Blast Furnace.

Hours in Factory	Worker	Active Time h.	m.	%	Kind of Work % Hard	Mod.	Light	Remarks:
12	Furnace Keeper	9	29	79	77·4	5·1	17·5	Tap the furnace.
12	First Helper	9	56	83	57·4	32·1	10·5	
12	Second Helper	9	15	77	66·9	6·6	26·5	
12	Cinder Snapper	9	17	77	64·0	17·9	18	
12	Lorry Man	7	39	64	Manipulating Controllers.			
12	Hoist Man	7	28	62				
12	Hot Blast Man	8	05	67	38·2	2·5	47·2	Fills. Signalled.

Open Hearth.

				%	
12	Charging Machine Operator	5	06	43	Quick. Many levers.
12	First Helper	3	16	27	
12	Second Helper	5	31	46	
12	Third Helper	4	26	37	
12	Ladle Craneman	6	12	52	Ladle takes iron to hearth.
12	Steel Pourers	3	36	30	
12	Brakeman Engineer	5	58	50	
12	Stripper Craneman	4	25	37	

Note from Report in 1902 to British I.T. Ass. Com.:—There is no pig-lifting, no hand-shovelling of stock. No hauling of charging barrows. All the tedious clay work around the hearth and incessant changing of tuyères is done away with.

Rolling Mills.

Hours in Factory	Nature of Work	1st Plant Time Active and %		2nd Plant % of whole time	
		h. m.	%	h. m.	%
12	Pit Craneman	7 07	59	8 31	71
12	Bottom Makers	3 17	27	7 28	62
12	Rollers	10 03	84	8 36	72
12	Roughers	7 10	60	7 20	61
12	Shearman	9 54	83	7 31	63
12	Conveyor Men	9 54	83	7 08	59
12	Cranemen	9 54	83	7 20	61
12	Scale Wheelers	10 18	87	6 48*	68
12	Chargers	5 00	42	10 27	87
12	Slab Car Operator	10 30	88	8 34	71
12	Greasers	10 30	88	10 40	89
12	Table Men	10 15	85	10 45	90
12	Screw down	10 30	88	11 16	94
12	Rotary Shearmen	10 50	90	10 55	91

* 10-hour day.

Bessemer Converter.

Hours in Factory	Nature of Work	1st Plant Time Active and %		2nd Plant % of whole time	
		h. m.	%	h. m.	%
12	Mixermen	10 24	87	7 34	63
12	First Regulator	11 04	93	9 37	80
12	Vessel Scraper	6 18	53	6 24	53
8	Vessel Men	3 27	45	4 37	38
12	Bottom Makers	9 30	79	9 17	77
8	Steel Pourers	6 33	82	6 54	58
12	Stripper Men	8 00	67	7 45	65
12	Ladle-liners	9 10	76	8 30	71
10	Stopper Makers	8 00	80	8 50	74
12	N.G. Engineers	9 20	78	6 24	53

(*b*) On the results of combining several movements in one operation much light is thrown by the articles of Max Weber, translated for this Committee by Mr. C. K. Ogden, of Magdalene College, Cambridge (Index D8). 'Complex operations,' like the stamping of tin sheets into boxes or the filling of such boxes by a machine whose movements are regulated at the will of the operative, are of extreme frequency in women's industries to-day and involve in all cases: (1) the feeding of the machine or generally the placing of the materials in position; (2) the moving of a handle or pedal; (3) the taking out of the finished article, all of which movements—often engaging different limbs—have to be timed in succession.

It should also be noted that a large proportion of the work in connexion with iron and steel making involves complexity of action. Thus all the 'Cranemen,' 'Hoistmen,' 'Operators,' cited on the preceding tables, have as their work the pulling of various foot-levers and handles which are to move the cranes, hoists, and charging machines exactly at the right moment and exactly to the right place; and, indeed, where, as is now particularly the case, machinery is being introduced extensively to transport the material about the factory—generally hung from cars on overhead runners—there the work of the 'carmen' will much increase the proportion of complex work performed in industry as a whole.

The importance of this question is shown by Weber, who quotes

Vogt as holding that 'operations involving will, memory, and association have a marked disturbing influence when they enter into combination with other operations,' and also that 'operations which are particularly closely related as regards the psycho-physical parts that they employ disturb one another in a particularly high degree'; further that, though 'after a certain period of habituation several combined processes can be made without any disturbing influence whatever,' there will naturally be a corresponding increase in fatigue.

(*c*) In the industrial world to-day there is the widest variation in the uniformity of any one worker's occupation—*i.e.*, in the similarity of the different actions in each recurrence of the whole operation. Machine-tending, for instance, involves constant nervous attention perhaps, but the muscular action varies continually according to what it is that goes wrong with the machine. In agriculture also a man's occupation is not uniform, nor yet in lumbering and transport—for soil and roads, plants, animals, and goods are always varying. Similarly in all organising and policing work the people dealt with vary. In building, 'navvying,' mining and stevedoring, repairing and washing, also, work is not altogether uniform, for there is a continual adaptation to different situations. In all assembling or fitting together by hand, too, there are generally certain slight dissimilarities in the parts which must alter the workers' actions in each recurrence of the operation. Soldering tins by hand is a further case of non-uniformity, due here to the necessity of reaching a certain standard even at the expense of added vigilance and added movements, and this applies all the stronger to the work of pure inspection.

But wherever the conditions of place are the same and the material used homogeneous, as in working with a machine on machine products, there will be found the quality of uniformity in the occupation.

(*d*) In studying here the *frequency* of the recurrence of any 'unit' operation we must concentrate on the frequency due to the simplicity of the work or to the (most economical) speed of the machine rather than any addition to such frequency induced by special systems of payment. These would be studied under Incentive (Factory Organisation).

It has been one of the results, if not the aim, of the industrial Division of Labour to simplify or 'specialise' the task of every individual so that he may become an adept by its frequent repetition. While in the old days the housewife boiled her jam but once a year, there are now factory hands that boil and boil day after day; while in work on a machine that must repeat its motions every minute or so, such as a metal-stamping press, the frequency can be reckoned in 'output per hour.' There are still processes, however, that have remained of small 'frequency.' The iron blast-furnaces are only tapped every four hours according to Mr. Farrell (Pres. of the U.S. Steel Corporation), and there is only one furnace to be tapped by each gang. In the open-hearth and Bessemer steel-making processes a gang goes from one hearth or converter to another, but the actual operation occupies considerable time in each case. Other infrequently recurring processes are found in tanning and in most 'finishing' trades where much time must be spent in bringing the article up to the desired pitch of perfection

(*e*) The intervals of recurrence of the whole operation is very *irregular* in the piecing up of the spinner and all machine-tending; but it is particularly irregular in dealing with people, as the tram-conductor, policeman, and telephone operator have to do. For the telephone operator, for instance, there is a 'curve of work' which depends mainly on the demands of the business and social world, and is of a shape well known to all telephone-company managers. In New York City, for instance, demand is at its maximum between 10 and 12 in the morning, and has a lesser maximum in the middle of the afternoon.

Recurrence is fairly *regular* in iron and steel smelting and very regular in all machine-feeding operations, such as stamping and pressing *where the machine is continually running* independent of the operator's will.

. . . . . .

The whole question of the affections evoked by different kinds of work, *apart from the particular actions* involved, may be summed up in tabular form in three columns, the first showing the relevant conditions of material, machinery, and organisation, the second the evocative characteristics of the work produced by such conditions, namely:

Great or little Complexity (C & c),
Great or little Uniformity (U & u),
Great or little Frequency (F & f),
Great or little Regularity (R & r),

and the third, the affections (states or feelings) of the worker evoked by these characteristics, that may be supposed to lead ultimately to general fatigue.

Material Condition	Relevant qualities often produced	Worl ers' Affections that result
Material:		
A. Natural	ur	
B. Machine-made	UR	Lack of Interest.
C. Human	ur	Worry (Interest).
Machine:		
Machine acting at will of worker	UFC	Worry. Monotony (Boredom).
Machine continually running:		
(*a*) Insertion of material or 'feeding' by the worker	FR	'Drivenness.'
(*b*) Attendance by worker only	fru Fru	Interest. Attentive Care.
Industrial Organisation:		
Great Specialisation	UF	Monotony.
Efficient 'Routing'	R	'Drivenness.'

Monotony in the worker would thus seem to be caused by a combination of great uniformity and great frequency of recurrence in the work; Worry by complexity of actions in combination with great frequency and little regularity of recurrence; Care (or strain of attention) by a combination of great frequency and little uniformity; the helpless feeling of being driven by a combination of great frequency and great regularity of recurrence; and Lack of Interest by that combination of great uniformity and great regularity usually coupled with

a complete absence, due to factory or economic organisation, of intelligibility or purposiveness in the work.

These unpleasant *and ultimately fatiguing* affections vary for different people, and some can be overcome by certain adaptations. Thus the sense of being driven can be overcome if the worker can fall into the rhythm of the machine (cf. Bücher, 'Arbeit und Rhythmus,' and Max Weber's 'Psychophysik' (Index D8). Again, seemingly uniform and frequently recurring work is pleasant to some workers, though it would cause monotonous feelings to others, according to Münsterberg ('Fatigue and Efficiency,' pp. 190 ff.), and nearly all individuals can to a certain extent automatise uniform and frequently recurring action, and by thus enabling themselves to keep their minds off their work can prevent monotonous feelings. This at any rate is the case with such proficient knitters as the Hausfrau, who can work and read simultaneously, and girls in the factory who can work and talk. How far so-called monotonous work will really evoke feelings of monotony—*i.e.*, of 'boredom'—would seem to depend very largely on individual tastes and individual powers, and at the same time it may be observed that uniformity prevents all anxiety, responsibility, or worry on the part of the worker, since there are never any new decisions to make or old decisions to regret. The question whether uniformity tends, therefore, to 'build character' or the reverse is, unfortunately, outside our scope.

SECTION I.B.—*Ventilation, Humidity and Temperature, and other 'Conditions of Factory Hygiene.'*

The latest research has resolved different 'degrees of Ventilation' as simply different degrees of Heat and Moisture combined. To quote Professor Lee:[1]

'Much experimentation has shown that the evil results of confinement in improperly ventilated rooms are caused not by the presence of toxic products of respiration, but by the heat and the humidity combined. Paul found that with human beings enclosed in a hot and humid experimental chamber, the unpleasant symptoms began to appear within a few minutes, and before there was time for the accumulation of supposed poisonous gases. When the air of the chamber was put into motion the temperature of the skin fell, the unpleasant symptoms disappeared very quickly, and the subject felt as if fresh air had been supplied. When the subject had been confined for a considerable time, and the symptoms had become well developed, the breathing of pure air through a tube passing from the subject's face through the wall of the chamber to the outside brought no relief. When, on the other hand, an outsider with his body surrounded by fresh air breathed from a tube the vitiated air of the chamber, no unpleasant symptoms appeared. Such facts make it clear that the symptoms are due to the action of the vitiated air, not on the lungs but in the skin.'

'We may therefore concentrate our attention on the effect of temperature and humidity. Prof. Lee thus summarises the effect of

[1] *Journal of Industrial and Engineering Chemistry*, vol. 6, 1914, p. 245.

damp and warm conditions in a disinclination or actual inability to perform active muscular work:[2]

'Beginning as a mere inertness, accompanied by sleepiness, which may readily be resisted for a time, it may pass into a genuine condition of fatigue, and ultimately into the exhaustion of heat-stroke. Haldane says of the Cornish miners of tin and copper: "They do not . . . . seem to be able to do more than a limited amount of work. The leisureliness of all work in the mine is in very striking contrast to what may be observed in any ordinary English colliery of about the same depth." Pembrey, after studying the effects of warm moist temperatures upon himself, medical students, and soldiers, concludes: "The results show definitely that a man is much less efficient in a warm moist atmosphere. . . . A man can do far more work with less fatigue at a low wet-bulb temperature than at a high one." Pembrey and Collis, in speaking of the physiological effects of the warm moist atmosphere of cotton weaving, say: "The natural tendency is for the nervous system to become less active, and for muscular work to be diminished. In a weaving-shed, however, the machine sets the pace, and the worker must neglect the dictates of his sensations, which are the natural guardians of his health and well-being. . . . It is not surprising, therefore, that at the end of a day's work, many of the weavers complain that they have no energy left, have no great desire for food, and need only drink and rest." Boycott says of mining in hot moist air: "My observations on miners . . . lead me to conclude that their power of doing work under these circumstances is quite small." Mr. Cadman, Professor of Mining in Birmingham University and late H.M. Inspector of Mines, gives more detailed observations to the effect that from about 25° C. (77° F.) wet-bulb reading, exertion begins to be accompanied by depression, and disinclination to work increases rapidly with an increasing wet-bulb temperature. At 27·8° C. (82° F.) "if clothes be removed and maximum body surface exposed, work can be done providing current of air is available." At 29·4° C. (85° F.) "only light work is possible"; and at 35° C. (95° F.) "work becomes impossible." Stapff observed in the construction of the St. Gothard tunnel that the labourers, working in an atmosphere often completely saturated with moisture, and with a temperature rising at times beyond 30° C. (86° F.) as measured by the dry-bulb thermometer, experienced not only great discomfort, but indifference, enervation, weariness, and exhaustion.'

As regards different temperatures separately from humidity, a chance of noting their result on working capacity is given by changes of season and weather. In 'Harper's Monthly' for January 1915, under the heading 'Work and Weather,' Prof. Huntingdon traces the variations in manual and mental work as the year proceeds.

Combining various workers' piece-earnings for the same weeks in the four years 1911-1914 in two Connecticut factories (one in 1911, the other in 1912-1914), Prof. Huntingdon found that the 'lowest wages are earned during January, then there is a rather steady increase

[2] *American Journal of Public Health*, vol. ii. p. 866 ff.

through February, March, April, May, and the first half of June. A little after the middle of June the amount of work begins to fall off and continues to do so for the next two or three weeks. Then, through July and August, the curve remains at a lower level than in June, but much higher than during the winter, a somewhat surprising fact. About the end of August people once more begin to work fast, and they go on at an increasing rate until the middle of November. Then the rate begins to fall, but recovers somewhat in December, and finally at the end of that month drops off very rapidly.' Testing the course of *mental* work by the marks awarded students at West Point and Annapolis U.S. Military and Naval Academies, 'approximately the same results' were found.

Prof. Huntingdon therefore suggests that 'the only satisfactory explanation of this seems to be that people's energy varies 10 or 15 per cent. from season to season,' and accordingly he correlates his yearly output curve with the variations in light, open-air life, and temperature that different seasons involve. But temperature he considers has far the greatest influence:

'It certainly looks as if there were a close relationship between temperature and work, but curiously enough the relationship is in part the reverse of what most people would expect. Low temperature seems much more harmful, and high temperature less harmful than is commonly supposed.'

Prof. Huntingdon then compares the output curve in the summer of each single year with the weekly mean temperature then prevailing, and finds that in general the summers of southern New England are less debilitating than the winters. It requires extreme summers, such as are experienced only once or twice in a century, to produce effects as harmful as those of an ordinary winter. Then, 'determining how fast people work on days having various temperatures, no matter in what month they come,' Prof. Huntingdon finds that 'at very low temperatures both mental and physical work are depressed. On days with higher temperatures activity of both kinds increases, the increase being slight at first. Mental work reaches its highest point at a temperature of 48° F., while physical work reaches a maximum at 59° F. for men and 60° F. for girls.

Turning back to his yearly output curve, Prof. Huntingdon sums up that during the part of the year when the temperature passes *beyond* 45 and 70 degrees 'people's work falls off sharply, and when the temperature approaches these limits work increases.'

One other feature of the curve is noted, however: 'between the limits (45° and 70° F.) (work) does not vary as one would expect, but tends to keep on rising all the time,' and suggesting that this is because the temperature keeps changing, and change is a stimulus. Prof. Huntingdon compares the work done in single days with the degree of temperature by which they differed from the preceding day; he finds that when the temperature drops, provided the drop is not excessive, 'human activity is decidedly stimulated.'

A further chance of comparing the result on working capacity of

different temperatures is afforded by the alternations of day and night, though in this case many other factory conditions are introduced as factors, such as the difference of sun and artificial light and differences in noise and room. There may also be important differences of habits and skill between night and day workers. From the economic standpoint, however, it is well worth while recording some researches on the comparative effect of day and night—firstly on accidents, then on output.

Referring to the work of Dr. Walter Abelsdorf's 'Die Unfallhäufigkeit in den gewerblichen Betrieben während der Nachtschicht' (Leipzig, Vogel, 1910) the Chief Factory Inspector's Report for 1910 says: 'It has been found in Germany that the industrial accident rate (calculated in proportion to the ascertained numbers at work) is less by night than by day. In explanation of this it is suggested that at night there are relatively fewer untrained workers, less crowding and interruption, less transport of material, and more leisurely and careful work, with correspondingly reduced output. Exceptions were met with, however: thus, there was a higher accident rate by night than by day in the machine-making industry in the Düsseldorf and Potsdam districts, and in chemical works in the former district, but not in the latter.'

These findings are not supported, however, by the experience of a large American iron- and steel-making plant published and exhibited at the San Francisco Exhibition, 1915, by the U.S. Department of Labour. In each department the accident-frequency rate was as follows:

Department	Accident Rate	
	Day	Night
Blast Furnace	204	229
Steel Works	218	224
Rolling Mills	150	160
Mechanical	122	389
Yards	139	399
Other Departments	69	227
For Total Plant	142	214

It is important to bear in mind, however, as will be pointed out in Section IV., that bad lighting may have a direct effect in causing accidents without affecting working capacity; so that the conflict in the conclusions of students may well be attributable to differences in the standard of lighting in the factories where they investigated.

As regards the *output* of night and day compared, the Curtis Publishing Co., of Philadelphia, very kindly presented records of the hours spent by a single worker on pressing ten thousand 'good impressions of the *Saturday Evening Post.* The average hours thus spent by fifty-three *day* men was 5·04 per man; by forty-six *night* men 4·78 per man. According to this, therefore, working capacity would seem slightly higher at night than during the day.

Section II.—*The Tests of Fatigue.*

To measure the results of fatigue accurately the 'test' chosen should (1) vary as the fatigue varies (*e.g.*, be a result of fatigue), and (2) vary with the fatigue only (*e.g.*, not be a result of other factors).

The tests here used particularly are: (1) The output of work, (2) the accidents occurring in the course of work.

In addition to the main tests of output of work and accidents, scientific use has been made of some other tests, which fall into three groups:

(1) Tests allied to the output of work test, such as the output of electrical or other power during working time, and the labour costs of the factory.

(2) Tests allied to the accident test, such as the proportion of mistakes or spoilt goods in the product.

(3) Medical tests of the after-effects of work, such as the prevalence of sickness and particularly nervous disorders attributable to overwork, and the comparison of blood-pressure and breathing (cp. Roth) and of cutaneous discrimination (cp. Griesbach) before and after spells of work.

This enumeration almost completes the non-laboratory tests of fatigue capable of statistical treatment. They are non-laboratorial in the sense that they are records (tests 1 and 2) of facts or of the results of facts (test 3) occurring in ordinary life. In the laboratory, on the other hand, either the fatigue itself is artificially produced or the tests specially invented, and thus certain circumstances of ordinary life are removed and the factors to be studied isolated; but though the 'analysis' or explanation of results may thus be facilitated, yet different factors besides fatigue are introduced such as a high average tension and suggestibility in the 'subject,' and these may make the conclusions inapplicable to industry.

All the non-laboratorial tests enumerated are capable of statistical treatment in that their discoveries can be stated numerically as certain quantities of one statistical unit. On the other hand, opinions of managers and foremen or inspectors or doctors in answer to 'questionnaires' as asked by Eisner, Bloch, Levenstein, and others, though they may suggest what statistics to collect, can hardly themselves be treated statistically.

The collection of these non-laboratorial statistics must always wait on the chance occurrence of events that permit comparisons to be made. Of such 'chances' there are for industrial output and accident statistics and some of the 'medical tests' two types.

One chance of finding statistically the influence of the factor of 'previous duration of work' on 'output' (or use of power) on accidents (or proportion of mistakes) and on the workers' health, is by dividing the working day into equal parts—the hour is generally the most convenient part—and by recording the output and the accidents occurring in each part, or the state of health after each part. Fatigue, it is presumed, will show itself, if anywhere, in the latter part of each working period (spell, day, or week); a comparison of the output, accidents and health in and after the later with those in and after the earlier parts will then show the influence of such fatigue as occurs in the course of the working periods.

It is this test of the 'distribution' over the working period of output and 'accidents' that we are here mainly using and discussing. This dis-

tribution may be represented either by tables giving actual numbers for each hour or part-period, or by diagrams measuring the time along their base and the amount of output or accidents vertically therefrom. The special advantage of diagrams is that sets of figures may be compared that have differently delimited hours, by measuring the amounts at slightly different points on the base.

To enable the distribution of output over the working-day to be treated statistically a unit of output must be found, in quantities of which the statistics may deal. This unit must (1) be similar in quality throughout the day, (2) be small enough to enable at least two such units to be produced during the day. In short the output must be 'repetition' work. Processes thus suitable for statistical record are found especially where a machine is used adapted to only one kind of work and possibly provided with an automatic register of the amount of work done. Where output does not lend itself to statistical compilation owing to heterogeneity (absence of Condition 1), the piece wages earned on the output might be recorded as affording a common denominator for the different kinds of output. The accuracy of this denominator would, as Weber points out, depend on how closely the piece rate for each kind of output was estimated exactly proportionately to the comparative effort required of the worker in each case (including under effort concentration rapidity and attention on the part of the worker). But where scientific management is not yet adopted, piece rates are settled empirically from results rather than by psycho-physical analysis, so that the time distribution of piece-rate earnings is at best a somewhat rough equivalent of output.

In statistics of accident distribution, the statistical unit is the individual 'accident.' This may be either every case treated or given first aid to as at Messrs. Cadbury's and Hans Renolds' or only the cases reported to Government 'certifying' surgeons and inspectors. Whatever definition of accident is adopted does not matter in statistics of the daily *distribution, so long as the definition is the same throughout the day.*

Another chance of finding statistically the influence of the cause 'previous duration of work' on the output and less easily on accidents occurs where the duration of the working day has been changed—where there has been a 'change in hours' either by way of a reduction through reorganisation, strike, or trade depression, or of an increase through overtime, &c. Here are compared the output or accidents per hour (or other unit of time) or the state of health, before and after the change. The importance of this comparison is that it makes it possible to seek the causes of accumulated fatigue (see Section I.). On the other hand, when such comparisons are made between different and sometimes distant periods, other factors besides duration of work are liable to have altered, or may even have been purposely altered with the change of hours of work. To attribute all differences in results to differences in duration of work becomes, therefore, scientifically speaking, more difficult.

In the following table of double entry are grouped some of the separate statistical investigations that have been made into Industrial

Fatigue up to the present. The method of grouping is (1) by kind of test adopted (in rows horizontally), (2) by kind of comparison made (in columns). The letter and number in brackets refers to Index of Documents, pp. 63-67.

Comparison Adopted.

Test adopted	Distribution over Working Time	Total before and after Change in Working Time
Output .	H. Marsh (D6) . . . U.S.A. Reports . . (i) Stamp Pressing (B5). (ii) Bessemer Converter (B6). Pieraccini (D5) . . Weber (D8).	Abbé at Zeiss's Optical Works (C8). See below. Fromont at Engis Chemical Works, Liège (C2). See below. Calcutta Factories (C6). U.K. War Office and Admiralty (C4).
Power used	E. Roth at Siemens and Halske (C1).	Abbé at Zeiss's Optical Works (C8).
Costs .	. . . . .	Associated Efficiency Engineers (C7). Commonwealth Steel Co. (C5). Sir Wm. Mather at Salford Iron Works (C3). See below.
Accidents .	U.K. Chief Factory Inspectors' Reports (B2). Departmental Committee on Accidents (B1). U.S.A. Reports (B5 and 6). American States Reports (B7–11). Belgium (B3). Bogardus (D7). Imbert (D2–4). Germany (B4).	
Mistakes .	Pieraccini (D5) . .	Kennedy (in 1843). See below
Sickness .	. . . . .	Fromont (C2). See below.

The following is a brief account, prepared by Miss Hutchins, of the results of the more important of the 'Change in Working Time' Comparisons.

In 1843 J. L. Kennedy, an investigator appointed by the Children's Employment Commission, gave special study and attention to the industry of calico cloth printing; and obtained information from a firm who told him they had tried to run the mill fifteen hours a day and had so large an amount of spoiled work that they were compelled to shorten hours. When they did so, the proportion of spoiled work fell, and the output was increased. Kennedy saw that machine tending was not, as had been supposed, purely mechanical work, but that the productivity of the machine depended largely on the skill of the operative and on his power to concentrate his attention, a power which was evidently much lessened when suffering from great fatigue.

In 1893 Messrs. Mather & Platt introduced the forty-eight hours week at the Salford Ironworks. This was avowedly an experiment to discover if hours could be shortened without endangering the trade, and the result was that with the forty-eight hours week production was actually increased relatively to the previous years when fifty-four or fifty-three hours had been worked.

Another experiment had been made recently at the Engis Chemical Works near Liège. The company had a sick benefit fund which was constantly depleted, and the manager became alarmed. They tried the effect of introducing three shifts of eight hours. The output equalled the previous output of ten hours' work, and the earnings, all piecework, equalled the previous earnings. The increase of output and wages per hour was about 33 per cent. The sick benefit accounts showed that under the old system expenditure had exceeded receipts; while under the new, receipts tended to exceed expenditure and that progressively. The effects on health and sobriety were remarkable, and the cost of production was reduced 33 per cent. per ton of roasted ore.

Ernst Abbé, after becoming manager of the Carl Zeiss Works in Jena, reduced the working day from nine to eight hours. In the result it appeared the men earned by piecework on an average about 3 per cent. more than they had earned in the previous year working nine hours, and the earnings per hour increased in the ratio 100:116. The men were unconscious of any special effort, and were surprised to find their earnings increased. Abbé came to the conclusion that the increased efficiency was physiological rather than psychological. If the need of recuperation after exertion is neglected, the effect is like a daily recurring deficit, and means actual loss in industry.

SECTION III.—*Do the Tests Vary with Fatigue?*—Are variations in fatigue indicated by variations in the amount of output and number of accidents?

That of the two tests we are mainly to use the output of work may be expected to vary and to vary inversely with fatigue is suggested by the very definition of fatigue as a diminution in the capacity for work. That the occurrence of accidents may also be expected to vary and to vary congruently with fatigue requires, however, some further proof.

Accidents may be divided as to their causation into those in which the human element entered and those in which it did not; those whose causes were partly psycho-physiological and those whose causes were purely mechanical or otherwise 'external' to the victim.

In the causation of many accidents the psycho-physiological state of the victim was probably one of the elements, though generally only as a condition enabling some mechanical cause to take effect. A dangerous psycho-physiological state may be either permanent or temporary, but in any case there is no reason why *as a rule* such a state should be more usual later in the working period than earlier unless it is connected with fatigue.

Quite a few industrial accidents, however, are caused purely mechanically by explosions, electric shocks, to which might be added accidents due to animals; others are attributable to recklessness, to the

inexperience of a learner, and even, in America, to ignorance of the language. But these dangers, mechanical or social, are present to the same degree throughout the day, and, therefore, the resultant accidents are as likely to happen at one hour of the day as at another. In both divisions, therefore, accidents not due to fatigue will not alter the *shape* of the curve of accidents that were due to fatigue, but will simply make its ups and downs less steep.

The effect of fatigue would therefore seem to be *under*-represented by the accident curve, but to what extent depends on the actual proportion of accidents that are not in any way attributable to fatigue.

Bogardus examined the causes of 2,203 accidents in Illinois in 1910 individually, and found that only 17½ per cent. 'were beyond the control of the injured.' This percentage of accidents would only include those *purely* mechanically or 'externally' caused (see above), and there must be an additional percentage of accidents due purely to psycho-physiological states other than fatigue.

If we take particulars presented by the Federation of Master Cotton Spinners' Associations to the Departmental Committee on Accidents (Index B1), out of 1,362 accidents occurring in all departments with over fifty accidents, *i.e.*, Spinning Rooms (pp. 683 and 687), Cardroom (pp. 685 and 686), and Weaving (p. 687), the events causing accident may be classified broadly as follows where 219 'miscellaneously' caused accidents are omitted.

	Fatigue contributable	Non-contributable
Knocking against machine	154	—
Kicking spinning carriage slip	134	—
Falling or making false step	200	—
Caught, *e.g.*, trapped between rollers	238	—
Cut by tool in use, &c.	139	—
Fainting	5	—
Breakage (of strap, &c.)	—	6
Cut or hit by falling object	59	—
Splinters	97	—
Scalded and burnt	19	—
Sprains, strains, and blisters	—	69
Climbing on headstock	23	—
	1,068	75

Now out of these events only 'breakage' and 'sprains, strains, and blisters' can have no element of fatigue in their causation, while 'cut or hit by falling objects' may be caused purely mechanically or may be due to the fatigue of the injured's fellow-worker. To all the other events the fatigue of the man injured himself may have contributed. For instance, a splinter is a physical material fact, but the worker's not perceiving it and avoiding it is psycho-physiological. Again, to 'climb on the headstock' may be reckless, but that such a feat should prove fatal at one particular time and not at another suggests on that occasion an element of fatigue. We may say, therefore, that broadly 93 per cent. of these cotton-trade accidents definitely had some psycho-physiological origin, and of these most were in all probability the result of fatigue. Similarly of industry as a whole, though some accidents are in no degree attributable to fatigue and result in smoothing down the

'time-distribution' curve of accidents, yet such accidents form a small proportion of all accidents, varying for different industries, but not likely to exceed 20 per cent.

The exact psycho-physiological *modus operandi* by which the tests I shall mainly use, *i.e.*, the output of work and the occurrence of accidents, may be expected to vary with fatigue (output inversely and accidents congruently) has been explained by Dr. Imbert, of Montpellier University, in a paper to the Congress of Demography and Social Hygiene held at Brussels in 1903:

'A result of the slowing down and decrease in the rapidity of the muscular contraction' (a physiological characteristic of fatigue) 'is that the speed of work, that is to say the quantity of work performed during a unit of time, will diminish as the expenditure of energy increases and fatigue becomes more intense. It follows that an estimate (*l'appréciation*) if not the exact measure of the speed of work should provide a method (*procédé*) and often a very simple one of discovering the existence of fatigue.

'The occurrence of which an accident is the result sometimes takes place with such suddenness that the worker may fall a victim at the very moment when he perceives the danger that threatens him or even before he sees that danger. In other cases on the contrary, the occurrence is less sudden, and the workman sees it coming and can often escape it (*s'y soustraire*) by a few rapid and energetic movements of retreat or protection. But it is then a question of making use of a movement which may not be more than a fraction of a second, and one may imagine from this how fatal the action of fatigue on the rapidity of muscular contractions and relaxation (*relâchement*) may be for the workman affected.

'Moreover, to estimate with a full knowledge of the causes the ability (*aptitude*) of a worker to save himself from a danger that threatens him unexpectedly (*inopinément*), one must consider the phenomena of fatigue other than those of physical fatigue. The conscious perception of danger, indeed the realisation of those voluntary movements which can save us, is a complex act taking its origin in a peripheric excitement (visual, auditive, &c.) and its end in muscular contractions after intermediate cerebral operations. . . . From already numerous experiments it is found that we can measure the duration of such a complex phenomenon and that such duration is far from being negligible in regard to the question here considered, and that further the duration is influenced by certain circumstances. By experiments it has been established that for a whole act relatively simple the total reaction time is notably longer when the organism is in a state of physical fatigue.'

These quotations from Imbert suggest that while the output-rate is largely affected by fatigue directly, by the very diminution of speed, the accident rate, on the other hand, is affected through the channel of decreased 'nervous' activity in attention, sensitivity, and speed of reaction to which Bogardus would certainly add the channel of less active muscular control. How far the output rate is also affected thus indirectly would depend on the nature of the work, and especially the nervous activities involved (see Section I.A), and channels through

which fatigue would act here especially would be a weakened activity in judgment and memory. At any rate, it seems likely that the output and the accident time distribution do not test fatigue at quite the same points. It is interesting also to note that if it were possible to record a time distribution of the *quality* of work (as measured inversely by the number of errors each hour) it would follow the accident rather than the *quantity* of work distribution in measuring fatigue indirectly and especially through the channel of attention, muscular control, and judgment and memory. The importance of this suggestion is that since such time distributions of errors are very difficult to record, the accident distribution may be taken as an equivalent test of the effect of fatigue on *quality*.

This whole discussion may be summarised, and here and there expanded in the following table:

Fatigue	Loss of Speed	decreases quantity of output; increases accident immunity and quality *slightly*.	
Fatigue	Loss of Intensity	Less Attention, Less Muscular Control	Decrease acc'dent immunity and quality mainly.
		Less Sensitivity, Longer Reaction	Decrease accident immunity mainly.
		Weaker Memory, Less Judgment	Decrease quality, accident immunity, and output equally.

Section IV.—*Do the Tests Vary only with Fatigue?*

All the possible factors have been enumerated which *besides previous duration of work* might be causing fatigue. It must now be pointed out that *besides fatigue* there may be other factors causing variations in the output and accident distribution. Though Imbert shows that output and accidents may be expected to vary with the degree of fatigue, he cannot show that either I output and accidents, II. the output only, or III. accidents only, do not also vary in amount with other factors besides fatigue.

I. All the factors that may influence both output and accident distribution 'immediately' without the interposition of fatigue may be considered in two groups:

A. Those factors which like fatigue itself are psycho-physical states in the worker.

B. Those factors which are some outside condition or fact.

A. For the full discussion of all the 'psycho-physical' component states which together with fatigue influence the 'work curve,' reference must be made to the translation of Weber's 'Psychophysik' (Index D8). Of these 'states' the most important for short working periods (the spell and the day) are 'Practice,' 'Spurt,' and 'Incitement.'

In 'practice' Weber sees the process which leaves 'the conscious will and the power of attention' free for application elsewhere, and

which 'probably means a quite direct saving of energy through the removal of pressure from the central nervous organ.' Its manifestation is the 'increase of facility, rapidity, certainty, and regularity of a particular action or operation through its frequent repetition.' The result on working capacity may be expected to be that 'at the beginning the increase in practice outweighs the early fatigue, so that the output curve as a whole moves upward,' but 'as the work continues the fatigue begins more and more to outweigh the increase of practice in its effect on the output.'

By Incitement (*Anregung*) Weber means a 'psycho-motor state' which 'arises in a purely mechanical manner from the work itself, and without the active intervention of the will,' and he supposes that it 'usually makes itself felt very shortly after work has begun, and after fairly short intervals, sometimes of about a quarter of an hour, suddenly vanishes away.' As Dr. Myers points out, the result of the loss of incitement is familiar enough when we return to a task from which we have been called away, even for a few minutes.

By Spurt (*Willensantrieb*) Weber means 'an impulse arising under special conditions and carrying sudden outbursts of energy.' 'Its typical effect is seen in short sudden rises in the curve at the beginning of work, after disturbances and almost equally regularly towards the conclusion.' It may be caused by the desire to earn more or to finish off well, or even by a smitten conscience, or by the desire to come up to a certain standard.

To these three component states we should like to add a fourth which the accident statistics collected will show to be extremely important. Weber came very near to noting this new component by its absence, when he says 'a man's driving power (*Antrieb*) is apparently also influenced in a negative direction by the tedium (*Langweile*) of his work and (at the beginning) by the consciousness of a long day's work before him.' I refer to the excitement that accompanies the anticipation of a rest, a change and food near at hand, with possibly also the satisfaction derived from work accomplished, the same frame of mind that makes schoolboys at the end of term exclaim with glee:

> 'In two weeks where shall I be?
> Not in this acadamee . . . '

This factor, like incitement, is not a manifestation of the will, but contrary to incitement it is due not to something 'in' the work, but something 'outside' it. Indeed, as Mr. C. K. Ogden has suggested, '*ex*citement' seems a 'peculiarly appropriate name for this feeling,' though if it is held too broad a term 'Anticipation' or 'Relief' might be used, or even 'Rally.'

Fatigue and the four other states we have considered important do not necessarily influence the course of accidents and output in the same direction. Fatigue and practice have indeed an entirely opposite effect, fatigue tending to increase accidents and decrease output, practice to decrease accident and increase output; as Weber puts it, the output and accidents distribution will show the result of a 'struggle between practice and fatigue.' Further, incitement, spurt, and excitement all

side with practice, though their influence will be felt at different periods, and, as in the case of fatigue, output and accident distribution may each be somewhat differently affected. The external factors conditioning Practice, Spurt, Incitement, and Excitement are the same as those conditioning fatigue, *i.e.*, Previous Duration of Work, Factory Conditions, the Nature of the Work itself and the state of the Worker; though any great effect of Factory Conditions on 'daily' Practice and Incitement is perhaps doubtful.

The following chart may make clearer the Causal Relations:—

Previous duration of work of certain workers in certain processes among certain surroundings	Condition:	Fatigue	Which results in	Output decrease. Accident increase.
Previous duration of work of certain workers in certain processes among certain surroundings	Condition:	Practice, Spurt, Incitement, Excitement	Which results in	Output increase. Accident decrease.

B. The 'outside' or non-psycho-physical condition which is of most importance as a factor in the time-distribution of both accidents and output without interposing fatigue is Lighting.

As regards this 'immediate' effect of lighting on output the Industrial Commission of Wisconsin found that a steel plant by just changing its system of lighting could increase its output at night by over 10 per cent.

As regards immediate effect of lighting on accidents: The National Electric Light Association have published a diagram correlating the monthly proportion of darkness, cloudiness, and sunlight in the city of New York with the monthly fatal accidents in 80,000 industrial plants for three years. In each 'correlation' the maximum is round January, and the minimum round July. Similarly the accidents per man are higher at night than by day (see Section I.B in the case of iron and steel works).

To a certain extent artificial and other weak lighting may increase accidents by fatiguing the eyes and attention, and hence lighting is included under the Conditions of Factory Hygiene likely to influence fatigue (Section I.); but to a larger extent the relation of accidents and lighting is 'immediate,' the distribution of accidents over the day being influenced by the growing objective invisibility of danger-points.

II. Factors besides fatigue that may influence the time distribution of *output only* are connected with the continuity of the work. If the work is not continuous: if the worker has to prepare his materials at the start of the day and clean up at the end, or if in course of the day he must wait either because his materials have not reached him, or on account of his machine breaking down, or if at certain times during the day the work must go faster than at other times owing to short time orders, &c., then in so far it is the events of the factory or outside economic circumstances and not fatigue that is affecting the output distribution.

III. Factors besides fatigue that may influence the distribution over time of day of accident occurrences only are:

(i) *The Magnitude of the Output.*—The greater the output the

greater is the exposure to accident, since the more specially dangerous movements will have to be performed so much the oftener.

A nicer test of fatigue than the absolute distribution of accidents would thus appear to be the distribution over time of accidents per *unit of output*. An absolute increase of accidents might be due to an increase of output, and that due in turn to spurt or some other check to fatigue, and thus an increase of accidents would measure decrease rather than increase of fatigue. Similarly an absolute decrease of accidents might be due to a decrease of output, and that due to increase of fatigue.

Unfortunately accident and output statistics are extremely difficult to correlate, since to secure sufficient accident data large numbers and long periods must be studied, while output data suitable to statistical treatment can only be secured here and there.

Where output or work is likely to vary greatly during the day, as in the tramway, telephone, or shop service with their rush hours, the accident distribution alone is quite unreliable. Separate reference to these 'industries' is omitted from all statistical tables, though they are included under Total Industry.

(ii) *The Kind of Process.* If at certain times of the day the workers studied are engaged in more dangerous work than at other times, as founders are in casting at 3 P.M. or so, then accidents will vary accordingly, without reference to fatigue.

SECTION V.—*Characteristics of the Actual Time-Distribution.*

A. GENERAL.

We have now a sufficient grasp of the different causes of fatigue and of the relation of fatigue to the two tests we are using, output and accident time-distribution, to be able intelligently to consider the figures given in the tables on pages 323-344 with a view to finding the solution to our central problem: What is the exact correlation of fatigue with the previous duration of work performed?

First, however, a word in explanation of this phrase 'previous duration of work.' The factory system that now prevails in manufacturing industry has standardised among many other conditions of life the workers' hours of labour. Except in a few continuous industries like iron and steel, the average 'employed' factory hand works 5½ or 6 days a week, 8 to 12 hours a day, and thus his very hours of work per week are standardised and often even ascertainable in 'Blue Books.' The distribution of the hours into 'spells' of continuous work differs considerably between countries. In America a five-hour spell, then dinner, then four or five hours more is the rule; on the Continent of Europe short pauses often occur in the middle of the morning and afternoon; while in England the day generally consists of two hours work, half-hour breakfast, four hours work, one hour dinner, four hours work, tea. This general standardisation applies also outside the factory to the building trades in full, to agriculture, lumbering, and mining as regards day and week, but not as regards spell, since breaks in the work are made somewhat irregularly according to opportunity and feelings. In iron and steel manufacture, however, there are no

breaks in the work at all, meals being taken as the work proceeds. Agriculture, lumbering, mining, and iron and steel works will therefore be left for separate consideration, the term manufacture being used to exclude them, though it may be taken to include building. Industry as a whole, when mentioned, will include all these trades, and transportation and commerce into the bargain.

Now, thanks to such standardisation of working times as large-scale industry has introduced, we may know at any given time of the day or the week just how long men in any given factory have been working since the beginning of the week, day, or spell. The output or accidents of that factory at all given times can therefore easily be correlated with the length or duration of work 'previously done.' Few single factories, however, have analysed their output or accidents according to time of occurrence, and to supplement them we have to fall back on figures collected by Governments for a whole State within which the times of work are likely to differ considerably. Such 'State accidents' are delimited into hourly periods either by the exact hours (*e.g.*, 7 to 7.59 or 7.01 to 8) or, as in Massachusetts, by the half-hours (*e.g.*, 6.30 to 7.30), but which of these periods corresponds to what hour of the working spell has only been roughly estimated from inquiries on the spot as to the usual working times. These working times are indicated at the head of each of our tables or in a note at the bottom. Accidents or output in hours which are certainly not worked full are not quoted. By thus omitting the hours of meal-breaks in our tables and leaving a space instead, the spells of work are clearly distinguished.

These tables, then, that follow on pages 323-344 show the output and accidents as distributed over the hours of spell, the spells of a day, and in some cases the days of a week. A yearly distribution could not illustrate the result of (*i.e.*, test) the fatigue of factory workers since they do not usually get a regular yearly holiday,[3] and it is therefore impossible to correlate output accidents to any 'duration of work since start of year.' There is no industrial year. To find the periodic fatigue as contrasted with the accumulated fatigue described in Section I., the only periods we can usefully compare are the days of the week, the spells of a day and the hours of a spell; with the questions in our mind—What is the weekly fatigue? the day fatigue? the spell fatigue?

The answer to these primary questions jumps to our eyes. As far as the figures before us show, there is little weekly fatigue, little daily fatigue, but a great deal of spell fatigue. In this nearly all our statistics agree remarkably.

The output and accidents of the different days that work full time never vary more than 10 per cent. from one another, and even then it is not always the later days of the week that have more accidents or the lower output.

In Belgium in 1907 (Table XIV.), it is true, Saturday is by far the most fatal day of the week (attributable in some measure to cleaning machinery in motion), and in the case of the English Engineering Trades (Table IX.D), especially locomotive manufacturing and shipbuilding,

[3] There are certain notable exceptions to this, such as the Lancashire wakes-week.

the comparative fewness of accidents on Thursdays and Fridays is explained by the fact that during slack trade men work in rotation, some only starting the week on Thursdays. But in all the weekly accident records of American States (Tables XI., XII.), the maximum of accidents per day seems to fall indiscriminately at any time of the week, and very often it is Monday.

A most interesting point occurs, indeed, in comparing English, French, and Belgian with German and American weekly accident curves, in regard to the number of Monday accidents as compared with that of other days. Thus according to the 'Aemtliche Nachrichten des Reichsversicherungsamts 1910' for Industrial Associations (mainly manufacturing), the proportion of weekly accidents occurring on each day of the week is as follows:

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1907 .	2·37	17·01	15·74	15·68	16·14	16·23	16·83
1897 .	2·15	17·45	16·67	15·71	15·71	15·34	16·97

which brings out Monday with the highest accident rate, and Saturday (especially as half-holidays are becoming more frequent) with the next highest, and the American figures agree on the whole with the German in the frequency of Monday accidents (Tables XI. and XII.). This has led many Germans and Americans to attribute such regular variations as there are in the weekly accident curve to practice at the start and fatigue at the end of the week; as we shall see, however, in the case of the single spell, practice has on accidents quite a negligible effect. A second school of thought has attributed the frequency of Monday accidents to the alcohol drunk on Sunday, and has even used the term 'Blue Monday.' In Belgium (Table XIV.) it is Saturday that has highest accidents, though, if the early closing on Monday were allowed for, Monday would come second; and similarly Saturday's accidents are highest, and Monday's about average in French figures collected by Dr. Imbert. But while Belgium and France thus occupy a middle position, England shows the exact opposite to Germany and America. It will be seen that, adding up cotton and the selected metal trades (Table IX.), accidents in England are highest on Friday, then on Tuesday, then Wednesday, then Thursday, and on Monday there are fewest accidents.

England, France, and particularly Belgium, are by no means 'temperance' countries, so that a new or at any rate a further explanation of the weekly accident curve seems required, not unconnected with the Saturday half-holiday. In England Sunday is spent in real rest, the drink or exercise—both fatiguing—being taken on Saturday afternoon; the result is that men start the week fresh and with few accidents. Abroad, just in proportion as Saturdays are worked full, and Sundays spent in work also, or in fatiguing recreations, so will Mondays have the first or second highest score in accidents.

Comparing the same spells of different days, the afternoon hours have more accidents according to the French figures presented by Imbert (Index D2-4), but our figures agree with his only in the case of the Motor Companies (Tables XX.-XXII.) and German Industry (Table XV.), though in all the American State figures the frequent,

but not universal, Saturday half-holiday may account for the comparatively fewer afternoon accidents there. But apart from these in the English cotton industry (Table IXA.), the Belgian industries, and the majority of single factories (Tables XVII.ff.), in all of which the comparison is fair, the accident rate seems slightly lower in the afternoon than in the morning. As regards output, there seems no general rule, and the question will have to be considered under the different varieties of work and conditions discussed in Section V.B.

We have assumed that the break between the two main spells is of an hour's duration. A *clear* exception to this is recorded, however, in Table XXII., where only half-an-hour is devoted to lunch. The result seems to be a very low accident rate in the hour immediately following the half-hour break, but after that an extremely rapid and continuous increase up to the last hour of the day, when half as many accidents again occur as in any hour of the morning. It is interesting to compare this curve with Miss A. M. Anderson's evidence before the Physical Deterioration Committee to the effect that 'in certain industries where it is the custom to allow only half-an-hour in the middle of the day for food very serious results are produced—in London, for instance—in the dress trades.'

But comparing the different hours of one spell we find in our tables variations up to 25 per cent. in the output, and almost up to 300 per cent. in the accidents (see Table IX.A, Cotton). This latter figure is all the more remarkable since, as was pointed out in Section II., those accidents that are due solely to mechanical causes are not likely to vary in amount throughout the day.

The actual course or direction of the variations, however, differs very much for accidents and output respectively.

In the case of *output* there is in every table an increase of the second over the first hour of the spell except for a very slight decrease in Table IV. (Machine Sewing) in the afternoon. This almost general increase is as much as from 24 to 38 in soldering, Table III. Col. 1 (A.M.), and from 85 to 106 in Hand Chocolate-covering, Table II. Col. 2 (A.M.)

After the second hour of each spell there is generally a gradual decrease till the last hour, though in the third hour the output may be yet higher than in the second. In the case only of Apparatus-covering (Table II. Col. 1), and of the Cotton Trade (Table VII.), is the last hour's output higher than that of the second hour of *one* of the spells, though in stamp-pressing (Table VIII.) the last *half*-hour is considerably higher in both spells. This general decrease is particularly marked in the case of soldering (morning spell Table IV. Cols. 1 and 2), where the second hour's output was 38·42 at Jacob's and 52·4 at Cadbury's; the fifth hour's output only 29·74 at Jacob's and 43·7 at Cadbury's.

The same general characteristics mark the course of the spell in the only other records taken of the hourly distribution of output made previous to this, those of Prof. Pieraccini, of Florence (Index D5), and of Dr. Howard Marsh, of New York (Index D6).

Dr. Pieraccini studied six typesetters in one shop and four in

another, each for a day. The total number of lines they set when added together is distributed as follows: first hour 205, second 255, third 222, fourth 211; then after lunch and a rest of two hours, 241, 206, and 160. Only in its first-hour maximum in the afternoon does this differ from our usual distribution.

Of Dr. Marsh's three records one refers to workers on a time-wage, and thus introduces a novel element; but in the other processes, in three spells out of the five the total output of all the workers shows the usual short increase or stationariness followed by a long and gradual decrease; the two exceptions—magazine wire-stitching morning and evening spell—have no decrease, their total output remains on the whole stationary.

It should be noted that in all the output tables we have collected the wages were wholly or partly paid by the piece, the gradual decreases in the output towards the end of the spell is presumably, therefore, not due to deliberate 'slacking': every slackening of effort would mean a loss of the workers' earnings.

In the case of *accidents* there is in every one of our twenty odd tables and graphs, except at Cadbury's and H. Renolds' (Tables XVII., XVIII.), a constant increase of accidents in the course of the first three hours of each spell, morning, afternoon, and before breakfast, unless of course there are pauses. This increase is particularly marked in cotton spinning, where the third hour has 665 accidents against the first hour's 316 in the morning spell, and 536 against 222 in the afternoon spell. In some of the American and foreign tables for whole States the increase of accidents apparent between the first and second hour in the morning, though not between the second and third of both spells nor the first and second in the afternoon, is attributable to a certain extent to the fact that the first row of figures given does not always represent a full working hour. However, if from the 'usual working-times' given at the head of each table we make some rough correction, the general increase of accidents seems to hold good of the early morning hours, and if we look at the Wisconsin and German accidents classified according to the number of hours' work already done, and thus free from uncertainty, we find this increase as much as 200 per cent. between the first and second hours of work (Table XVI.).

After the third hour, accidents usually increase still further, but this depends rather on the total length of the spell, for we find that in whichever is the last hour of the spell (fourth or fifth) the accidents decrease, so that the accident distribution or curve may most accurately be said to reach its maximum on the penultimate hour of the spell. This increase up to the penultimate hour holds good so long as no mid-morning or mid-afternoon pauses occur, and where the last division of the spell is really a whole hour and not merely as in cotton (Table IX.A) and in Massachusetts (Table XI.) a half hour rated to the hour. But exceptions are found in the afternoon spells at Hans Renolds' (Table XVII.) and at the Cadillac Works (Table XX.) in some of the Tables dealing with smaller numbers (Tables XVIII., XXIII., and XXIV.) and therefore the more liable to 'error,'

and finally in several of the figures originally collected by the U.S. Federal Bureau of Labour, namely those of Indiana manufactures (morning) (Diagram I.) and of the American Cotton Industry (Diagram III.).

The divergence of this latter set of figures from the majority, however, is to a large extent due to the unusual hourly limits adopted by the U.S. Bureau of Labour, *e.g.*, from 10.01 to 11 instead of 10.00 to 10.59. This at first sight seems a trivial difference, but commonsense backed by experiment shows that factory occupiers are inclined to return all accidents occurring between, *e.g.*, 9.55 and 10.10 as 10—hence the importance of the question in which period to place the exact hour. The U.S. Federal method results in pushing back the maximum accidents.

The decrease in accidents from the penultimate to the ultimate hour of the spell mentioned already varies in amount very greatly. It is slight in all the Illinois figures, only from 1,485 to 1,438 in the total (Table XIII. Col. 4) in the morning and from 1,382 to 1,327 in the afternoon; but the decrease is very great in some single factories, notably Hans Renolds', in the morning, from 375 to 252 (Table XVII. A.M.), the National Cash Register 308 to 181 (A.M.) and the Cadillac Motor Company from 152 to 88 in the morning, and in the afternoon (where the decrease sets in earlier) 200 to 116 to 94.

That this falling-off is not entirely due to a fall in output, and, therefore, in the risk, may be seen by the fact that, even where output is humanly variable as in the processes in Tables II. to VIII., output never falls more than 15 per cent. from the penultimate to the last hour of spell.[4] That this falling-off is not due merely to a fall in the number employed owing to lunch or the end of work coming sooner, is shown by the accidents of individual factories where the exact times worked were ascertainable, and are stated in Tables XVII. and following, but furthermore in all State-collected records most detailed inquiries were made on the spot to ensure that, in all figures of hourly accidents given, the number employed at each hour was the same unless otherwise stated. In short, in the last hour of the spell there is a true decrease in the accident rate per given number of men and per given amount of output, or, at any rate, a check to the increase.

In the case of the statistics for whole States, the question of which is the last hour of the afternoon spell is rather hard to settle, since individual factories will quit work at different times, and though some indication is given by the heading over each table 'Usual Working Times,' evidence for the afternoon decrease of accidents must be sought mainly from the figures of single factories where the exact times of work are ascertained (Tables XVII., XXIV.).

The individual investigators of the time-distribution of accidents that have gone before us have failed to observe this decrease of accidents at the end of the spell. Bogardus, because he studied only

[4] Account must be taken of the fact that our output tables only give processes under piece wage where there is little likelihood of slacking. However, even under time wage discipline and set standards and the speed of the machine would prevent any very much larger falling-off in output.

the accidents of one year in Illinois (Table XIII. Col. 7), of which 246 happened to occur in the fourth hour of the morning spell, with 257 in the fifth; while 227 occurred in the third and 260 in the fourth (and probably last) hour of the afternoon spell; Imbert because he was too intent on fatigue and failed to notice considerable drops at 11 A.M., at any rate, in some of the very curves he gives in his diagrams (*Revue Scientifique*, September 24, 1904, page 388) and Table XV.D.

In the very last half-hour of the morning spell, it is interesting to note a rise of the rate of accidents over that of the preceding hour in almost every case where this period is separately recorded. In the English cotton industry this rise is from 623 to 651 in the morning and 512 to 615 in the afternoon (Table IX.A), and in the morning spell in Massachusetts (Table XI.A and B) while the pronounced rise for 'Total Industry' may be due to some industries diverging from the normal lunch hour, yet there are rises of accident in the last half-hour of the morning in the Building, Wool, Rubber, Paper, Printing, and Autocar Industries, whose midday hours are fairly normal.

Alluding to their accident statistics of metal-work, cotton (in U.S.A.), and Indiana and Wisconsin manufactures reproduced here respectively in Diagrams I., III., and IV., the U.S. Federal Report (page 97) speaks of the 'remarkable accord from group to group': 'Here are four sets of figures collected by different agencies in different parts of the Union at different times and covering different industries, each agency working independently of the others. Yet the figures thus gathered show striking similarity.' Yet these particular figures, as can be seen in the tables, are among the more irregular that we have recorded; and compared, for instance, with the Massachusetts, Illinois, Ohio, and individual factory accidents, differ among themselves quite considerably. In fact our figures agree with one another to such an extent, particularly those of accidents, that we are justified in speaking of a 'normal' time-distribution of output and of accidents, or considered inversely, accident immunity. The shape of the output and accident-immunity curves for a five-hour spell may for purposes of illustration be summarised as follows:

Hour of Spell	Output	Accident Immunity
1st	small	very great
2nd	very great	great
3rd	great	fair
4th	fair	*small
5th	*small	fair

* Where there are only four hours in the spell, strike out the last output, but the fourth accident hour.

In seeking an explanation of this 'normal' time-distribution of the accident rate and the output in a spell of manufacturing work, let us concentrate on the illustrative table. Here we find the four same degrees: very great, great, fair and small, succeeding one another in both the output and the accident-immunity column, though earlier in the spell with accidents than with output. Now both output and accident immunity vary inversely to fatigue; these four decreasing degrees, therefore, may well be measuring an increase in fatigue.

The only other possible cause that could by itself explain the rise in the accidents at any rate during the morning and afternoon is the drinking of alcohol before starting the spell. This explanation has been advanced by the Temperance Scientific Federation of Boston, and taken up by certain employers. To prove this contention, however, it would have to be shown firstly that the most debilitating effect of alcohol on control occurs just about four hours after its drinking, and not earlier or later, and secondly that such alcohol drinking is a regular habit among the workers.

The first point is far from established either scientifically or from everyday—but not necessarily personal—experience. All that we can say for certain is that if alcohol is taken at all in large quantities, the attention and muscular control that avoid accidents are lost immediately, and in the first hour.

The second point can certainly not be established at all in some of our records. The women cotton-spinners (of Table IX.A), the picked men workers at Hans Renolds', at the Motor Companies, at the National Cash Register Company, and the girls at Jacob's and Cadbury's and the Denison Manufacturing Company (of Tables XVIII. and following), are certainly not all drinkers, yet all of them show the same accident 'curve' as other and possibly hard-drinking employees.

If it be only fatigue, then, that can explain the middle hours, what of the first hour of output and the fifth hour of accident immunity that are left over? Here the explanation must be different in each case, and such a difference may well be, since, as it was pointed out in Section III. p. 299, variations in accidents and output are not always measuring the same psycho-physical activities. It is now contended that the small output in the first hour is due to 'practice' and that the fair accident immunity in the fifth or last hour is due to anticipatory 'excitement' (see Section IV.), both pulling in an opposite direction to fatigue, and here more than overcoming the fatigue effects; that this excitement does not affect the output at the end of the spell, and that, contrary to all expectation, this practice does not affect the accidents at the beginning of the spell.[5] This contention, founded on the facts in the tables below, is backed by the somewhat theoretical suggestions of Section III. There it was advanced that the main psycho-physical activity directly measured by output-rate variations was the changing of speed, and, by Weber's very definition, practice is a removal of pressure from the central nervous organ manifested in an increase of facility, rapidity, certainty, and regularity; but, further, that the main psycho-physical activities specially measured by accident-rate variations were attention and muscular control, and on these activities of the central nervous system a 'psychomotor state' of excitement would presumably be far more

[5] If, as was suggested in Section II., a curve of errors or mistakes would run a similar course to the accident curve, it is interesting to note the conclusion of Binet et Henri in 'La Fatigue Intellectuelle' that for adding and memorising the second hour of work, though faster, is less accurate than the first. Practice seems to decrease errors no more than accidents. Pieraccini's curve of errors (Index D5) confirms this in the afternoon but not in the morning.

potent than a state like practice, that is removing pressure from the nervous centres.

Now, if this explanation of the agreements and disagreements in the ascertained time-distribution of accidents and output respectively be correct, the following would be the psycho-physical diagnosis of a spell of factory work considered chronologically.

First hour: Fingers, arms, body and mind after their rest are working slow, but sure. To increase the pace and even perhaps to concentrate attention is uphill work and a fight against subjective feelings of sloth. In an emergency, however, muscles could be perfectly controlled.

Second hour: Body and mind, getting into their stride again, are working very fast, but not perhaps so exactly. Feelings of sloth are conquered, but there is a terrible long prospect of work ahead. However, as work is running easily, the mind may think of pleasanter things: attention scatters.

Third or third and fourth hours: Body and mind running on, but attention lost. If any sudden danger threatens or emergency arises, it may not be quick enough perceived, and when perceived, muscles may not be quick enough to prevent an accident; they can continue rhythmically and automatically at the same work, but for any change of movements that may be suddenly called, there is insufficient *control*.

Last hour (fourth or fifth): Body no longer running automatically with the same ease, an effort of the will required (spurt) to keep speed up; but the end is ahead, with food and rest; the attention awakes and control over the muscles is braced up—danger is better perceived and more quickly avoided. At the very end, however, even this new attention and control may tire, as indeed the whole body is tired, and only a rest can bring recovery.

B. Particular.

The agreement within the accident and output 'time-distributions or curves' was sufficient to justify the use of the term 'normal distribution' for industry in general and the discussion of its causation. Now, however, we may examine each time-distribution or curve given in the tables more closely, so as to describe any differences between them and to correlate such differences in the output or accident curves with differences in the conditions of each (see Section I.). The main conditions whose results our tables thus enable us to seek are:

1. Conditions affecting the factory hygiene and particularly temperature.
2. The nature of the worker: sex and age.
3. The nature of the work.
4. Factory organisation.

1. How far differences between the individual output and accident curves are attributable to differences in atmospheric conditions influencing the hygienic state of the factory may be gauged from Table XVII., where the accidents occurring at Hans Renolds' are analysed into summer and winter accidents.

According to Professor Huntingdon (see Section I.B), temperature is particularly debilitating at its extremes of heat and cold; we should therefore expect the lowest output and most numerous accidents in winter between 8 and 10 A.M. and, if at all, 5 and 7 P.M. (earlier and later factories are not working full); in summer from about 12 A.M. to 3 P.M.; the whole year round, then, minima of output and maxima of accidents should occur round 9 A.M., 2 P.M., and 6 P.M. But, when we look at the accidents at Renolds' (Table XVII.) we see clearly how the seasonal variations are only a minor factor when compared with fatigue from previous duration of work. In the total the maxima of accidents are not at 9 A.M., 2 P.M., and 6 P.M., but from 11-12 A.M. and 3-4 P.M., after three hours' and one hour's work respectively. Temperature, however, certainly appears as a modifier of the influence of fatigue from previous work; in winter the cold hours 8-10 A.M. have a much higher proportion of the day's accidents distributed to them than they have in the total; and similarly in summer the hour 3-4, though here it would not have been heat so much as the after-effects of heat, that would be potent.

From the figures it is impossible to infer, of course, whether extremes of temperature modify the accident distribution by directly producing dangerous circumstances such as fingers numb from cold, or whether extreme temperature acts rather as an indirect influence on accidents by enabling a duration of work to result more surely in fatigue (see Section I.).

2. The second main condition whose results can be sought by comparing different curves is that of the nature of the worker, and mainly his age and sex.

In the accident distribution of the Illinois manufactures (Table XIII.) it has been possible to distinguish women's accidents and also accidents to girls and boys under eighteen; in the accident distribution of the English cotton industry (Table IX.A and Diagram III.B) women's accidents are also separately classed and similarly the accidents of boys of eighteen or under in the comparison of earlier and later 'work-hours' (Table IX.B) in iron and steel and engineering.

One divergence which women's and boys' curves show from the normal occurs in the women's high accident rate in the morning as compared with the afternoon spell. In the English cotton industry (Table IX.A), the average of the hourly accidents in the morning spell and in the afternoon spell is for men respectively 261·8 and 239·6; for women 155·4 and 99·6; in the Illinois manufactures similarly, the hourly average morning and afternoon is for all workers 1,212·6 and 1,212·0, for women 28·80 and 24·25.

The main divergence within the spell from the normal which women's and boys' accident curves show is the almost complete absence of the normal decrease in accident in the last hour of the spell. In the cotton trade, there is a continual increase of women's accidents throughout all spells and similarly in the Illinois morning spell for women and boys, and there the boys' accidents between 5 and 5.59 are particularly high considering how many leave work at five.

The divergence shown between men and boys in comparing the ninth hour's accidents with the earlier hourly average of accidents (Table IX.B) seems to vary for the different industries. Thus, while in shipbuilding all males have in the ninth hour of work 143 per cent. the accidents they have in the first hour, boys only have 128 per cent. But in auto manufacture and iron and steel foundries boys have in the ninth hour 200 per cent. and 196 per cent. the accidents they have in the first hour, while males of all ages have only 132 per cent. and 153 per cent. It is only therefore in these industries that boys' accidents diverge appreciably from the normal by rising still higher; but the height of the rise is significant.

The explanation of boys' and women's continued rise in accidents throughout the spell would seem to be either a lesser power of anticipatory excitement or a stronger fatigue overcoming this excitement. The women's fewer accidents in the afternoon, however, would seem to exclude the stronger fatigue explanation for them. Lesser anticipatory excitement (therefore the only explanation left) may be something psycho-physical in the woman, but more likely it is due to the fact that for most women the end of the factory spell does not mean hope of a rest and food, but the certainty of more work in the preparation of food.

3. In examining how far differences in the output and accident time-distributions are attributable to differences in the factor 'Nature of the Work,' reference must be made to Section I.A, which dealt specially with that factor. There it was advanced that there were certain characteristics in any single craft or process that were peculiarly important in evoking affections akin to fatigue in the worker. These characteristics were 'concentrativeness,' 'persistence,' complexity, uniformity, frequency of recurrence and regularity of recurrence. A good opportunity of studying single occupations or crafts as apart from whole industries is afforded by our output figures in particular. It is to these figures that we turn, therefore, for the results of what we called the 'evocative' characteristics.

First it must be observed, however, that, owing to the statistical necessity of securing a frequently and regularly repeated output (see Section II.), the varieties of output that our tables exhibit cannot include infrequent and irregular operations. The characteristics chiefly differentiating the processes are therefore (*a*) concentrativeness and persistence; (*b*) complexity; and, above all, (*c*) the degree of uniformity.

(*a*) Movements concentrating or focussing their tax on local muscles are found in the processes of covering chocolates by hand (Table II. Col. 2) and in sandwiching and stencilling biscuits by hand (Table V. Col. 4), and here in both cases we find the output closely following the normal distribution as far as the morning spell is concerned; but in the afternoon spell the output decreases very slowly, and in stencilling does not reach its maximum till the third hour. Moreover, in the case of the chocolate-covering, the output in the afternoon is higher generally than in the morning.

This difference from the normal distribution is attributable to the

fact that the small local muscles, though easily fatiguable, are also soon rested in the mid-day break and will either work better in the afternoon or will tire then less easily. Abbé (Index C8) found indeed that in the Zeiss Optical Works a reduction of hours increased the output per hour of the finer handwork less than of the coarser machine work. And here we may refer again to Dr. Marsh's (Index D6) records of girls wire-stitching magazines; after a break from 5.30 to 6 'there was a marked recovery and a maximum rate till 9.30' (page 36). Machine-sewing also to some extent focuses work on the hands and fingers, and here again (Table IV. Col. 3) we find a high afternoon output after the local fatigue has been given an hour to recuperate, particularly where the frequency of operation, *i.e.*, the number of buttonholes to the hour, is very high and the fingers, therefore, have to be all the quicker.

Of movements concentrating their tax on the central muscles, building may be cited in particular, and also all the pursuits included under mining, lumbering (forestry), and agriculture, though their hours of work are somewhat irregular. A useful output distribution would be impossible to collect in these industries, owing to the heterogeneous work and working conditions; but, failing this, separate accident curves from different sources have been collected and plotted in Diagram IV. for building, Diagram V. for mining, and Diagram VI. for lumbering and agriculture. The astonishing feature of these 'time-distributions' is their similarity to the normal curve for the more strictly manufacturing industries (*cf.* Diagram I.). In building and mining, however, there is an earlier decrease of accident in the afternoon spell, attributable, since the eight-hour day prevails here, to an earlier close of work. In lumbering and agriculture the dips in the German curve at 8-9 and 4-5 are probably attributable to short meal-breaks; it should be noted that about half the work called lumbering is performed in sawmills with quite regular working hours and meal-breaks.

Several examples of work that involves nervous concentration have their output and accident time-distribution recorded.

Judgments of distance and of quality, including the activities of sensitivity, comparison with memorised standard, and muscular control, are found in machine-sewing, where the material must be directed under the needle absolutely correctly (Table IV.); in tin-labelling, where the label must be pasted exactly square (Table V. Col. 2 and Table VI.); in soldering and in tin-straightening, where, as in all skilled work, a definite standard of quality must be obtained (Table III. and Table V.). Now, it is in all these processes that we find the output curve most normal. The afternoon's output is somewhat less than the morning's, but in both spells the maximum output occurs in the second, or, where the first period recorded is half an hour, as at Peak, Frean's (Table V.), in the first hour and a half or second hour and a half. After this there is the gradual decrease of output, till the last hour's output may only total about 80 per cent. of the maximum for the spell, less if it is the fifth hour (as general in the morning), more if it is the fourth hour (as general in the afternoon). The total of the records of output of the

three examples of soldering tins recorded at three different factories (Tables III. and V. Col. 3) is as follows:[6]

Hour of Spell	Morning	Hour of Spell	Afternoon
1st	114·06 tins	1st	119·43 tins
2nd	167·44 „	2nd	165·42 „
3rd	159·59 „	3rd	163·23 „
4th	157·27 „	4th	155·95 „
5th	138·96 „		

and the average hourly outputs added together of the three examples of hand-labelling of tins recorded at two different factories (Tables V. and VI.) is as follows:[7]

Hour of Spell	Morning	Hour of Spell	Afternoon
1st	593·7 tins	1st	602·6 tins
2nd	669·0 „	2nd	622·9 „
3rd	687·9 „	3rd	611·0 „
4th	624·7 „	4th	(not given in one case)
5th	574·3 „		

Great *attention* for, and quick reaction to, a cue is involved in much of the wool and cotton industries. A conclusive output curve for these industries is extremely hard to give, since, in nearly all processes, the machine sets the pace and the human element only enters in filling, tending, or emptying the machine; and the figures we have collected in Table VII. show the conflict between the human and the mechanical 'work-curve.' But it is interesting to find that (Table IX.) cotton and wool are the only large industries in Massachusetts in which accidents are by far more numerous on Friday, the last full working-day of the week, than on other days. A similar statement can be made of textiles in Belgium (Table XIV.) on Saturdays, and in England cotton accidents (Table XIV.D) increase regularly throughout the week quite in contrast to the engineering and foundry accidents. These figures, combined with the steepness of the rise in hourly accidents during all three of the English spells (Table IX.A and Diagram III.B), suggest cotton and textiles generally as including some of the most fatiguing processes found in industry.

An example of work that is not 'persistent' and involves a large proportion of rest or lack of activity is provided by iron and steel making, some average proportion of active time to full time in that industry being given in Section I.A. It should be added also in the words of Mr. R. A. Bull (Index C5) that 'though the difficulties of the work are not constant but periodic, the work is distinctly arduous, physically and mentally, and carries a responsibility which puts a man's nervous system in frequent high tension.' This industry is also remarkable, however, in that the men at the blast-furnaces, Bessemer converters, open hearths, and in the rolling-mills take no breaks even for meals throughout a spell of eight to twelve hours; for this reason the iron and steel accident and output curves were not

[6] Weighted roughly in proportion to numbers and days at work; *i.e.* Cadbury's ÷5, Peek, Frean's 1, Jacob's×3.

[7] Table VI. Col. 1 is reduced to average per girl, but there is no other 'weighting, since numbers×days at work are not very different in each case, *i.e.* 8, 20, and 18.

comparable with others in the discussion of industry in general (Section V.A).

But turning now to Table VIII. Col. 2 and Table X., we find that the normal course of the four- or five-hour spell is not reproduced in the twelve-hour spell. There is no gradual increase of accidents in the first three quarters of the time, nor gradual decrease of output in the last three quarters. On the contrary, there seems to be a series of waves. The total accidents by day increase up to a crest in the fourth hour (9-10), decrease to a trough in the seventh (12-1), increase again to the ninth (2-3), and then decrease for the rest of the spell. By night crests occur in the second and ninth hours, troughs in the seventh and last hours. At the beginning of the night, however, there is additional repairing, and this may account for the early crest.

To calculate how far these accident curves diverge from the normal, we might consider the twelve-hour 'shift' as a four-hour 'spell' multiplied threefold. On this basis, the decrease in the last three hours corresponds strictly to the decrease in the last hour of a short spell due to anticipatory excitement, while the increase of accidents in the first four hours of the shift corresponds to the increase between the first and second hours of the spell, attributable to fatigue. The only hours not reconcilable are the fifth to the eighth (10 A.M.-2 P.M.): to correspond to the four-hour spell, accidents should be increasing; as a matter of fact, they form a trough in the curve. This trough may possibly be correlated with the midday or midnight meal, which would first produce a fall in accidents through anticipatory and then positive excitement while being taken; secondly a sudden rise while its digestion was conflicting with the work in hand. But that all these lesser forces should cloak or overcome the effects of fatigue must be attributed to the main peculiarity of this work, namely, the repeated intervals of rest at the end of each operation, which allow of 'recovery.'

In studying the separate departments of iron and steel works, it should be noted that the mechanical department and the yards usually have meal breaks, but betweenwhiles work actively all the time. In consequence, the fluctuations of their accident curve are more marked and are actually (not merely proportionately) more similar to the normal. So many different processes are included in these departments, however, that special attention to the figures given is not worth while.

In the output curve of the Bessemer converter (Table VIII. Col. 1) are seen the same waves up and down and even less regular. Here the effect of 'non-persistence,' especially combined as it is in this process with a relative infrequency in the recurrence of the operation (about three times to the hour), would make the factor practice of more weight than the factor fatigue and likely to last almost to the end of the day. This may account for the very gradual increase of output in each successive two-hour period, if we except 8-10 because of changes and repairs and 12-2 because of lunch and digestion during work. The general drop in the last two hours would on that supposition be due to the final overcoming of practice by fatigue.

(*b*) The most highly complex processes of those recorded in our

tables are the stamp-pressing, where levers have to be worked as well as material inserted and removed (Table VIII.), and complex to a lesser extent is the machine-sewing. In all these processes the afternoon output compared with the morning is higher than the normal, the average per afternoon hour compared with the average per morning hour being 40,676 to 40,047 in the stamping-press work, and 111·72 to 97·1 in the machine-sewing at Kettering (Table IV.). In other respects the curves differ, no doubt owing to the fact that stamping-press work is highly uniform but not concentrative, while machine-sewing is fairly variegated but tiring to the fingers (see above). In explanation of increase of output during the day for both these complex processes, it is interesting to note the following extract from Weber:

'Experiments show . . . that fatigue sets in more slowly in the case of disturbed or complex work than where there is no disturbance; indeed, in the hours at the end of a spell the output is often very much greater where work is disturbed than the normal increase which results from practice would lead us to anticipate. These results, which suggest that complex work is less fatiguing and more easily acquired by practice, are only apparently paradoxical. . . . The paradox is explained by the simple fact that the disturbed operation—that is to say, in the case of complex work, each of the individual acts into which it can be analysed—begins at a very much lower point in virtue of the disturbance. Hence the output increases with continuous habituation and inner adaptation to the disturbance or to the other work very much more quickly, until it reaches its maximum, than is the case with uninterrupted operations. This is due to the fact that not only the results of practice, but also the gradual adaptation to the disturbance, make their influence felt and are only fully realised when the work is practically at an end.'

(*c*) Of great uniformity or repetitiveness is the work with the metal stamping-press, and of this particular process we are lucky in having both accident and output time-distribution. Covering chocolate by apparatus is also uniform in that the same rack is always handled instead of the individual chocolate creams, as in hand-covering. This process, however, is not general enough to yield sufficient accidents for useful statistical comparisons.

Turning first to the output distribution in these uniform processes given in Tables VIII. and II., we find that in both cases 'the curve' differs from the normal in increasing right throughout the spell, except, in each case again, for the last hour but one of the afternoon spell. In the last half-hour of the stamp-pressing spells the increase is sudden enough to be attributable to 'spurt.'

The two processes differ, however, in that the output is less in afternoon than morning with the apparatus-covering, but greater w the stamping-press.

The explanation of the specially high afternoon output of stamping-presses was given under complexity, but the increase of output during the spell in both these uniform processes is due probably to the power

of most individuals to automatise processes that are uniform and frequent. 'This means,' to quote Weber, 'that with frequent repetition an ability is produced to perform an operation even without any conscious use of the will and of the power of attention for the requisite separate functions of the psycho-physical system, and finally the operation actually succeeds better without any effort of attention at all.' Further, according to Weber, automatisation seems to be helped to a large extent by 'rhythmisation' of the work, 'because this considerably facilitates the carrying out of the typical reactions without articulated will-impulse.' Great regularity as well as great repetition (uniformity) and great frequency is important, then, according to Weber, in increasing ease of work, and the time-distribution of the output of stamp-pressing and apparatus-covering which have these characteristics would seem to bear out this contention. Fatigue seems, except in the penultimate hour of the day, to be more than counterbalanced by a sort of prolonged practice. But to say, therefore, that monotony would decrease fatigue would be to fall into the confusion of terms pointed out in Section I.A. It is only when so-called monotonous work does not evoke monotony that it becomes less fatiguing.

Turning next to the accident distribution in the uniform process of stamp-pressing (Diagram II. and Table IX.c), we find that it does not differ from the normal distribution very materially except in the earlier onset and larger scale of the decrease of accidents at the end of each spell and in a somewhat greater accident-rate in the afternoon both shown in the American figures (Diagram II.). These divergences would suggest that, if anything, excitement in anticipation of a change is greater where the work is more uniform, and that the attentiveness and muscle-control which, as we have suggested, accident-distribution specially indicates become weaker than usual towards the end of the day when the work lacks variety.

4. Finally some attention must be given to the influence of different *systems of factory management* in diverting output or accident distribution from the 'normal curve'; and for the question of human fatigue the most important part of any system of management is the devices to ensure speed in individual operations and in the operation or action of the factory as a whole.

Hitherto we have regarded the speed of operation as involved in the nature of the work, assuming that for any given process there was some average and standard human rhythm or some definite rate at which a machine was most economically and efficiently run. Yet this natural speed may, so to speak, be tuned up or down, and of late, to judge from working-class opinion, there has been a good deal of tuning *up*. The degree of tuning or 'speeding up' of operations depends on the enforcement of discipline, on the 'incentive' of remuneration (whether time-rate or some system of piece-rate), on the speed of automatic machines, or on mechanical devices such as moving bands propelling the work through the factory.

Besides tuning up of speed of operation we must take account of a tuning up in the general action of the organisation, ensuring unremitting

flow of material with the use of every minute of a man's work-time, and closer supervision with an increased demand on the man to come up to the standard.

To isolate this factor of tuning up of efficiency, of the *intensity* of work, it is only possible to compare the output and accident of *single factories*; *whole states* will include all varieties of efficiency. But in comparing these single factories there are limitations, too, in the matter of their output distribution.

If in comparing an output curve in a less intensive with one in a more intensive factory it was found that during a spell the latter did not drop so fast as the former, it might be an indication of less fatigue under the intensive system, but again it might be due to the greater incentive to keep up speed. In short, the significance of the output curve is, on this point, ambiguous.

Turning to the accidents of single factories, however, we have a chance of useful comparison in the distribution at the Ford (Table XXI.), Cadillac (Table XX.), and Northway (Table XXII.) and at Hans Renolds' (Table XVII.) Motor Companies. At each of these engineering works efficiency has been carried to a very high pitch as compared with Metal Working in general (Diagram II.) or Auto manufacture in general (Table IX.B).

The distinctive feature of the accident curve in all these shops is the higher rate of accident in the afternoon than in the morning. Thus:

	Morning Accident Rate per hour	Afternoon Accident Rate per hour
Hans Renolds . .	317	338
Ford Motor Co. .	222	235·5
Cadillac ,, . .	121	141
Northway ,, . .	93	98

On the other hand, in Metal Working generally (Diagram II.), if we except the Massachusetts curve, which includes Foundries with their regular afternoon casting, the afternoon rate of accident is lower than the morning, and similarly of the Massachusetts 'Auto' Industry (Table XI.B, Col. 1).

We may couple this contrast with that between the Iron and Steel Making and all other naturally more persistent industries. Both bring out the fact that scattered irregular pauses, be they due to the nature of the material or to a hitch in factory action, all tend to relieve the 'psycho-physique' and to put a check to fatigue. Bogardus is very right when he attributes present-day fatigue in the factory in great part to 'unrelaxed tension.'

Further evidence of the fatiguing effect of intensity of work as apart from its extension and duration in time may be sought by comparing the accident rate in English industries in this present decade with former times when the work was more 'extensive' but less intense. In this comparison, however, it is rather difficult to isolate the factor of intensity; other factors have changed, too, of which the amount of dangerous machinery and the guarding of that machinery are the most important. Since these two most important factors affect accidents

oppositely, however, and thus more or less cancel out, it would be worth while giving the rate of accident per 1,000 employed for two or three separate decades respectively if only it were certain that the standard of reporting were the same in each case. The Home Office Committee (Index B1) appointed in 1909 'to inquire into the causes and circumstances of the increase in the number of reported accidents,' collected many such statistics as suggested above, but found 'an almost unanimous expression of opinion from witnesses of all kinds that the fuller reporting which has taken place during recent years accounts for a very large portion of the increase' (p. 9). But though the Accident Committee was thus unable to secure statistical confirmation they report that 'much of the increase (of accidents) was attributed to a general raising of the standard of effort in all spheres of life' (p. 13).

The new school of 'scientific management' in America has also devoted some thought to the fatiguing effect of 'intense' work. Mr. Knoeppel, for instance, in his book 'Installing Efficiency Methods,' carefully distinguishes 'strenuousness' from efficiency and holds that 'any standard determined should be one that a man can attain day in and day out without injury to his health of body or mind' (p. 109). This 'Standard Time' is reckoned at about the mean of a man's average and highest speed under unimproved conditions, with provision for rest often amounting to 16 per cent. or 20 per cent. of the whole time and enforced by clock at intervals varying for different kinds of work. A familiar example of the efficiency of such a system occurs in F. W. Taylor's 'Principles of Scientific Management.' For 'heavy labour' where the man's strength is exerted by either lifting or pushing something which he grasps in his hands, it was discovered that for each given pull or push on the man's arms it is possible for the workman to be under load for only a definite percentage of the day. For example, when pig iron is being handled (each pig weighing 92 lb.) a first-class workman can only be under load 43 per cent. of the day (p. 5). This scientific 'law' was then applied at the Bethlehem Steel Works, and resulted in the men's earnings (at a constant piece rate of $3\frac{9}{10}$ cents a ton) jumping from \$1.15 to \$1.85 a day.

To this now classical case of the pig iron may be added that of a machinist in the employ of the New England Butt Company, who was unable to complete his standard task per hour at a lathe turning metals till a notice was posted up bidding him rest twelve minutes after every forty-eight minutes' work.

Outside these individual studies, Scientific Management has perhaps not spent enough time searching scientifically for the laws of fatigue before setting its standard intensity of work; yet, if once these laws are discovered, then it is only to a really scientific management that we can look for the application of the discovery. In the hope of this consummation to our labours the significance to industrial organisation of the researches chronicled above may be sketched roughly in the following sequence:

1st. The importance of the *rôle* played by fatigue and other inner states of the individual worker. It is not a monopoly of mental work to be influenced in quantity and quality by the human disposition. For

the efficient management and organisation of factory and office, account must be taken of the human element just as much as of the material and the machine.

2nd. The importance of the rest-pause. A break in the work would seem to shed its influence all round; it causes a bracing excitement that avoids accidents beforehand and brings on after it a new lease of working capacity. More important than the length of working day seems the length of spell: the splitting up, the breaking up of continuous periods of work.

3rd. The importance of the nature of the work in modifying the onset of fatigue. In uniform repetition work causing 'subjective' feelings of monotony 'objective' fatigue seems far less effective than in the nerve-taxing work of attending to a loom or of labelling and soldering accurately in place.

4th and finally. The importance of taking account of and studying fatigue, and of adapting accordingly the hours of labour in each kind of work.

SECTION VI.—*Statistical Tables and Diagrams.*

TABLE I.—DAILY OUTPUT.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	%	%	%	%	%	%
A.	19·2	19·5	19·2	18·4	18·3	—
B.	19·2	19·7	19·9	19·8	19·3	—
C.	93·61	96·45	100	96·79	98·64	99·54
D.	92·69	95·61	100	96·91	99·67	*99·18

A. and B. German-American Button Co., Rochester, N.Y. Daily output for six weeks in percentage of the week, the average time worked each day being exactly the same.

The figures refer to the whole button-sawing department.

A. For selected average weeks.

B. For consecutive weeks.

C. and D. Collected by Weber of Westphalian weavers Index D8. C. and (D.*) minding one or two looms, D. minding one loom only. 100 represents the maximum day.

TABLE II.—CHOCOLATE-COVERING OUTPUT.

Messrs. Cadbury, Bournville.

10 couples and 4 individuals for 10 days, in September 1903.
Conditions.—Normal. Dinners supplied at cost price.
Workers.—Girls over eighteen.
Surroundings.—Good.
Payment.—Flat piece rate.

The Process.—Apparatus work (in couples):
(1) Put middles on rack (weight 2 lbs.).
(2) Dip rack in solution and shake.
(3) Reverse rack on paper.
(4) Fit in the misplaced chocolates.
(5) Place paper on table to cool and fetch more middles.
Posture: Half-standing, half-sitting.

Handwork (singly).
(1) Dip middle in solution.
(2) Mark pattern with fork or finger.
(3) Place in position on table.
Posture: Sitting.

Relative Hourly Variation.
Average of hour's output = 100.

Time	Apparatus	Hand	Hour of Day, Hour of Spell	
9–10	88·3 (1)	85·5 (2)	D1	S1
10–11	93·9	106·5	D2	S2
11–12	106·35	98·6	D3	S3
12–12·30	118·4 (4)	88·6 (5)	D3½	S3½
1·30–2	96 (2)	101 (3)	D4	S½
2–3	98·55	107·6	D5	S1½
3–4	94·4	107·4	D6	S2½
4–5	97	103·2	D7	S3½

Notes.—Here (1) 15 mins., (2) 10 mins., (3) 5 mins. spent in 'preparations' are averaged; and (4) 10 mins., (5) 5 mins. spent in 'clearing up' are averaged. No clearing up included in the 4–5 figures since work ends at 5.30.

TABLE III.—SMALL TIN-BOX SOLDERING OUTPUT.

W. & R. Jacob & Co., Dublin.	Cadbury Bros., Bournville.
10 workers for 10 days.	7 workers for 1 day.
Sept. 1914.	Feb. 1915.
Workers.—Girls aged 17–25.	Boys aged 15½.
Work.—Standing up.	Sitting down.
Pay.—Piece rate + standing wage.	Day + piece wage.
Surroundings.—Normal.	Normal.

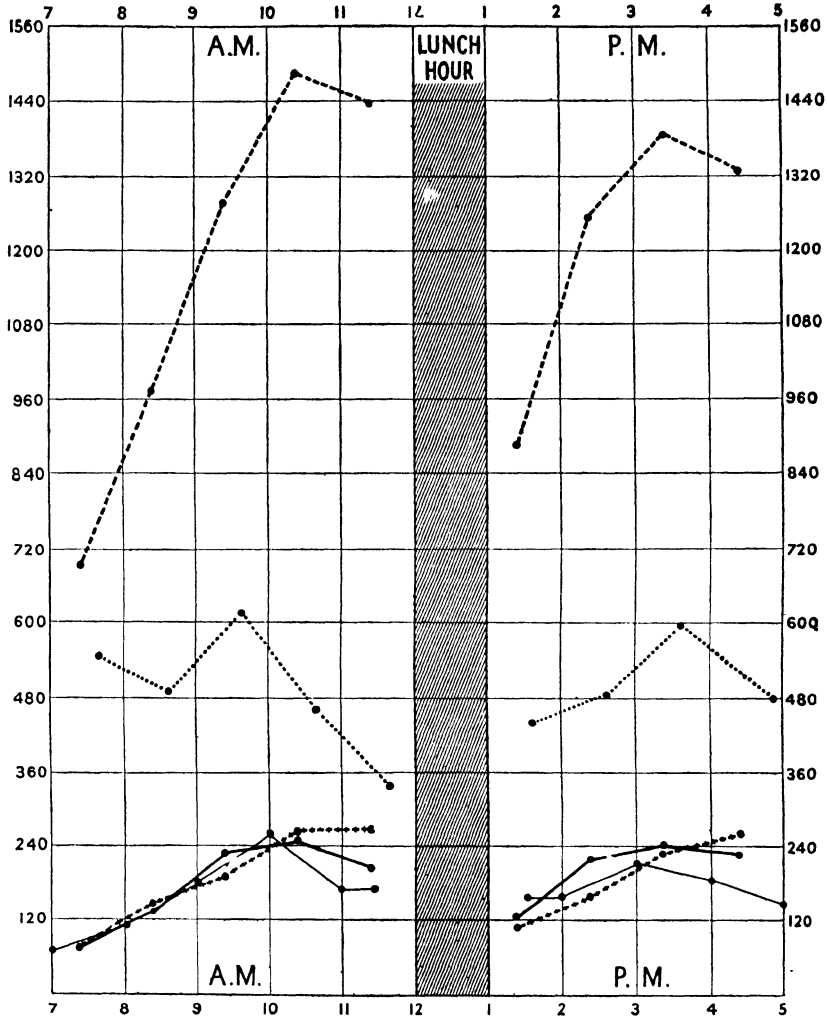
Average rate of tins per hour per day.

Clock Time	Jacob's	Working Hour (D of Day, S of Spell)		Cadbury's	Clock Time
8–9	24·3*(*a*)	D1	S1	46·8	7·45–8·45
9–10	38·42	D2	S2	52·4†	8·45–9·30
10–11	35·29	D3	S3	47·1	9·30–10·30
11–12	35·03	D4	S4	44·4	10·30–11·30
12–1	29·74	D5	S5	43·7	11·30–12·30
2–3	26·62	D6	S1	45·1	1·30–2·30
3–4	37·39	D7	S2	48·7	2·30–3·30
4–5	37·06	D8	S3	42·9	3·30–4·30
5–6	34·93*(*b*)	D9	S4	40·8	4·30–5·30

Notes.—*(*a*) 7 minutes averaged for preparation. (*b*) 6 minutes averaged for clearing up.

† Averages to the hour.

DIAGRAM I.—ACCIDENTS IN GENERAL MANUFACTURE.



Illinois 1910 (Bogardus) — Wisconsin 1908

Index No.: D7 (*Cf.* Table XIII. Col. 7.) B12

Illinois 1911–13 — Indiana (3 yrs.) — Minnesota

Index No.: B7 (*Cf.* Table XIV.) B5 B10

TABLE IV.—MACHINE-SEWING OUTPUT.

	Queen Mary Workroom, Piccadilly. Oct.–Feb. 1914–15.		Linnel & Wallis, Kettering June 1915.
Conditions:			
Workers.—Girls aged 18-25			
Surroundings.—Ordinary rooms, bared of furniture.			Normal factory.
Payment.—Piece rate (flat)			
Process.—Foot-driven machine. Making flannel belts. (1) Running. (2) Cutting holes. (3) Affixing tapes. (4) Stitching.	By hand.	Foot-driven machine. Buttonholing. (1) Cutting the holes. (2) Buttonholing with machine. (3) Snipping off threads.	Power-driven machine. Buttonholing.
	10 belts worked at a time through each sub-process.*	3 doz. holes worked at a time.*	
Range.—7 girls for a total of 55 days.		3 girls for a total of 44 days.	4 girls for three weeks each.

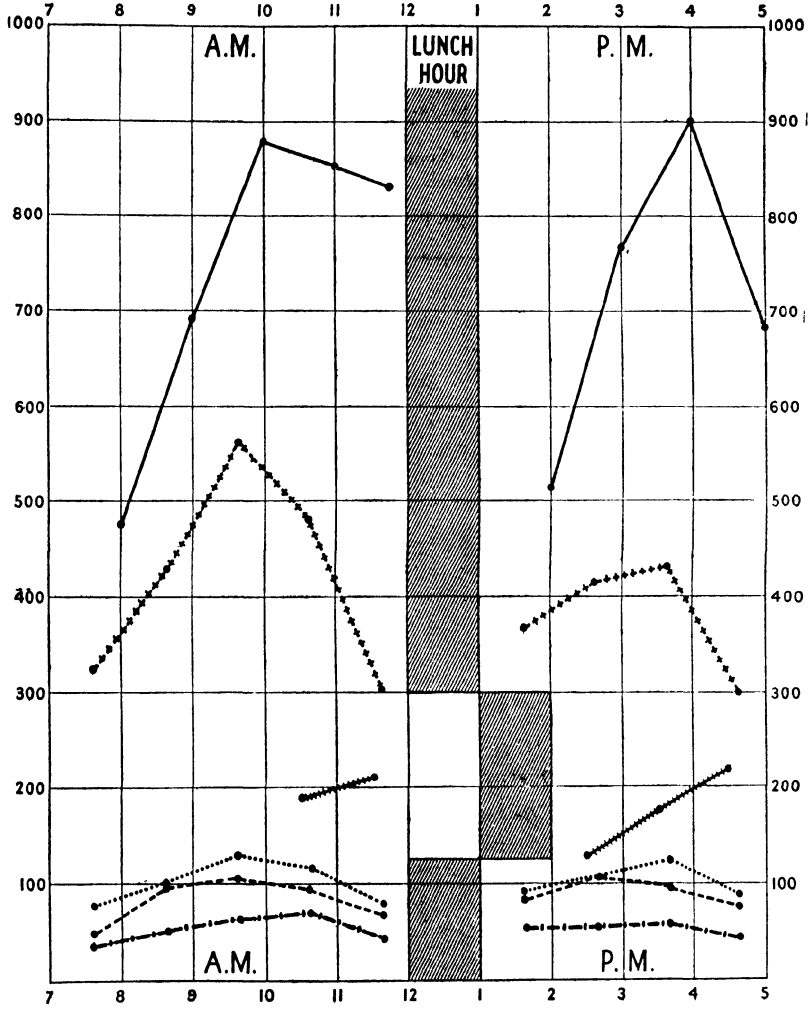
Average output per day.

Time	No. of belts per hour	No. of holes per hour	Time	No. of holes per hour
			7.30–8	†
8.30–9	†	†	8–9	99.5
9–10	3.51	20	9–10	96.5
10–11	3·53	19·6	10–11	102·5
11–12	3·60	19	11–12	89·8
12–1	3·51	18·3	12–12.30	†
			1.30–2	†
2–3	3·51	17·4	2–3	125·60
3–4	3·46	17·3	3–4	110·25
4.15–5.15	3·37	4–5—16·93	4–5	109·85
5–15–6.15	3·18	5–6—16 93	5–6	101·17

* The figures had thus to be compiled by converting time spent per unit of output (10 belts and 3 doz. holes) into rate of output per hour. This necessity has tended to smooth down short fluctuations.

† Output not recorded.

DIAGRAM II.—ACCIDENTS IN METAL-WORKING



Mass. (and Foundries — Press Hands ····· Other Metals -·-·- U.K.

Index: B9. Table XIA.

Note.—Danger of Casting in Foundry increases afternoon accidents. (See preface to Table IX.B.)

Men Women

U.S.A. Index: B5

Index: B2

Cf. Table IX.C.

Note.—Most ⅞ usual Lunch Hour: 1–2.

TABLE V.—PROCESSES AT PEEK, FREAN, & Co. April to June 1915.

Work.—	9 lb. Tin. Straightening.*	Tin. Labelling.	4 & 9 lb. Tin. Soldering.	Biscuit. Cream stencilling and sandwiching.
Numbers.—	6 for 6 days.	3 couples, 6 days.	6 for 6 days.	6 couples for 6 days.
Workers.—	Girls 21–24 years.	Girls 20–28 years.	Girls 17–24 years.	Girls.
Pay.—	Piece-Bonus.	Piece-Bonus.	Piece-Bonus.	Piece-Bonus.
Surroundings.—	Normal.	Normal.	Normal.	Normal.

Average rate per hour per day per individual:

	of tins.			of trays of biscuits.
8–8.30	151	148·4	31·8	3·50
8.30–9.30	170·4	165·2	41·7	3·99
9.30–10.30	171·25	162·7	44·3	3·92
10.30–11.30	168·75	156·3	43·3	3·95
11.30–12.30	138·6	147·3	41·0	3·62
Dinner	—	—	—	—
1.30–2.30	160·6	144	39·55	3·63
2.30–3.30	170·9	157	43·51	3·78
3.30–4.30	165·4	150·2	43·47	3·87
4.30–5.30	149·7	150·7	43·0	
5.30–6.0	—	—	33·97	

* Each tin has different-sized dents differently placed, all to be hammered straight with mallet and wooden anvil.

† Output not recorded.

TABLE VI.—OUTPUT. HAND-LABELLING OF TIN-BOXES.

Report of Mr. Greenwood to the Fatigue Committee, 1914.

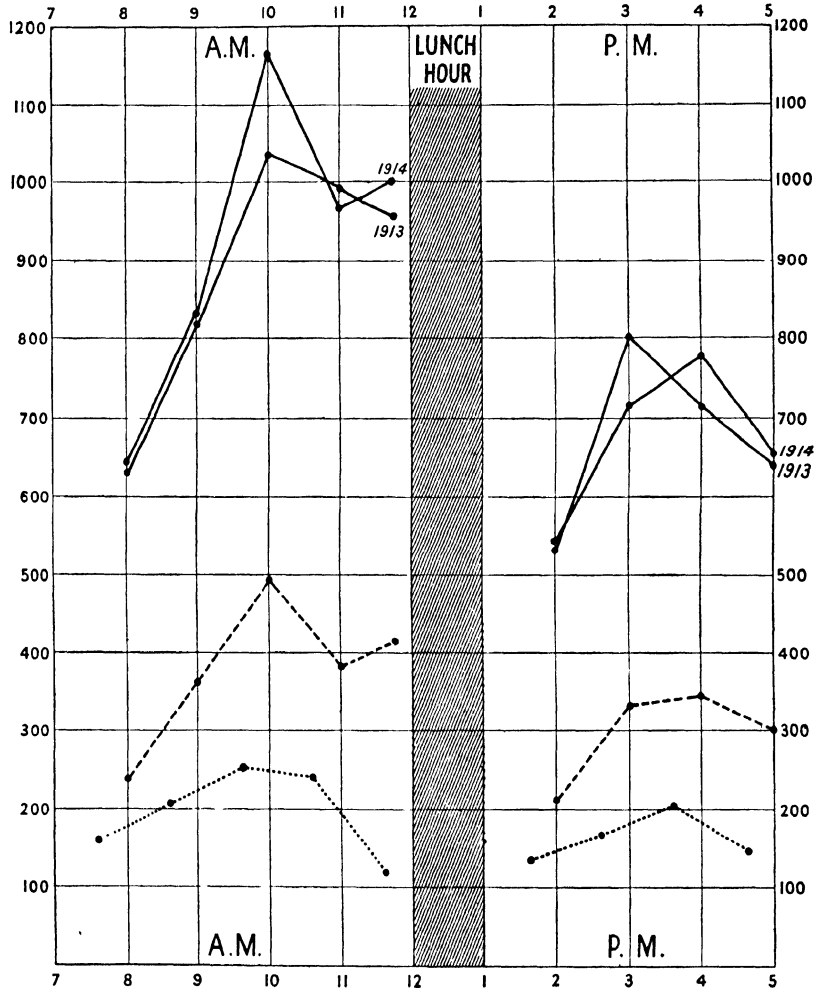
Hours of Day.	Total. 8 girls. One day.	Average. 4 girls. Average of 5 days.
7.30–8.30	2,032	191·3
8.30–9.30	2,123	238·4
9.30–10.30	2,282*	240
10.30–11.30	1,922	228·2
11.30–12.30	1,663	219·1
1.30–2.30	1,921	218·5
2.30–3.30	1,956	221·5
3.30–4.30	1,938	218·6†
4.30–5.0	1,430‡	

* Ten minutes (10–10.10) spent at lunch is averaged.

† For 4 days average. ‡ Rate per hour.

DIAGRAM IIIA.—ACCIDENTS IN TEXTILES.

Times of Work.—Mass. 7-12 1-6: 56 Hour Week.
Southern States 6-12 1-6,15: 60-72 Hour Week.



Massachusetts Cotton ------ Massachusetts Wool ..... U.S.A. Cotton

Index No.:	B9	B9	B5
Illustrates Table IX.A.		IX.A.	—

TABLE VII.—COTTON OUTPUT.

Barlow & Jones (Manchester), Aug. & Sept. 1914.

Processes where human element enters most into Output.

Hours of Day.	3 Men, 6 looms each. 3 days each. Weaving. No. of Picks per Loom.	2 *Scutchers.* 4 days each. Blowing. No. of Laps per Scutcher.
6–7	4 96	4·5
7–8	5·55	4·62
8.30–9 30	4·82	4·06
9.30–10.30	5·50	4·25
10.30–11.30	5·25	4·44
11.30–12.30	5·67	3·94
1.30–2.30	5·05	3·81
2.30–3.30	5·60	3·94
3 30–4 30	5·59	3·75
4.30–5.30	5·45	4·00

Two Slobbing Frames for four days.
Average time spent per day per set.

Sets (in order of time)	1st.	2nd.	3rd.	4th.
Minutes spent on set.	114	113	120½	126

TABLE VIII.—OUTPUT.

U.S.A. Federal Reports on

Iron and Steel Industry. (*b*) *Women and Child Wage-Earners.* (*c*)

	Output of Bessemer Converter. Two vessels, 8 months. No. of Blows		Stamping-presses (*a*). 23 machines, 1 to 7 days each
	Day Shift	Night Shift	Day only
6–7	1,208 } 2,477	1,191	—
7–8	1,269 }	1,284	37,631
8–9	1,213 (*d*)	1,175	39,855
9–10	1,146 (*d*)	1,164	40,201
10–11	1,292 } 2,647	1,346	40,316
11–12	1,355 }	1,320	11–11.30 42,234 per hour.
12–1	1,222 } 2,415	1,213	39,156
1–2	1,193 }	1,182	40,592
2–3	1,349 } 2,759	1,416	41,258
3–4	1,410 }	1,406	40,373
4–5	1,191 } 2,392	1,297	4–4.30 42,010 per hour.
5–6	1,201 }	1,167	—

NOTES.

(*a*) 'The speed of these machines depends entirely upon the operator, since for each piece formed he must actuate a treadle.' (Automatic Register.)

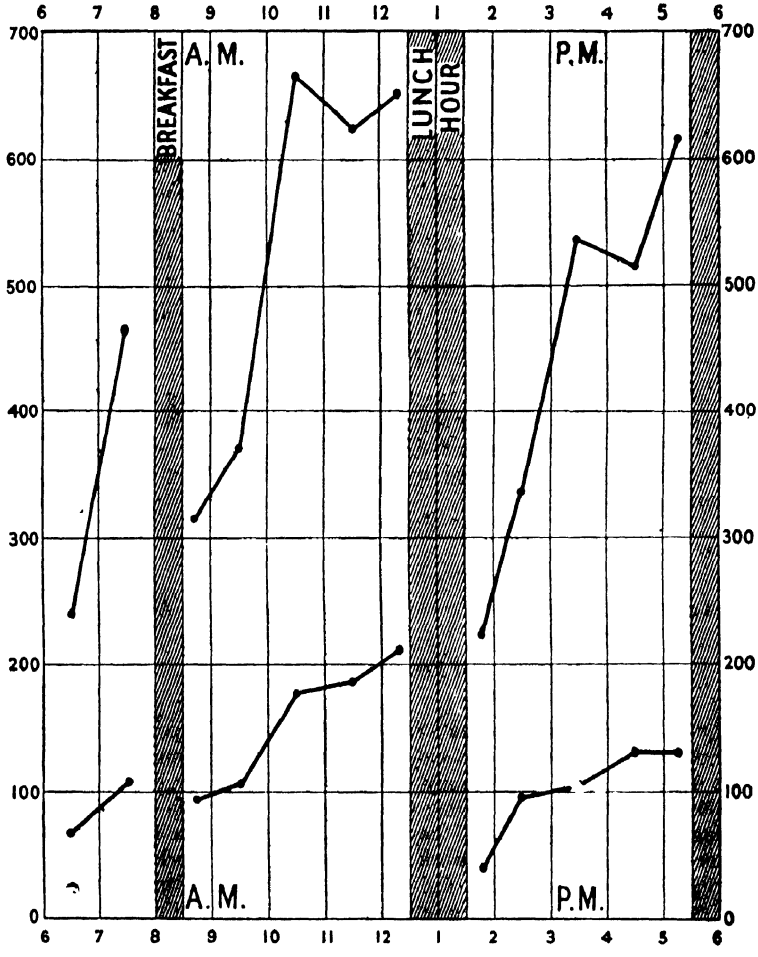
(*b*) 62nd Congress, 1st Session, Doc. 110, Vol. IV. (Index B6).

(*c*) 61st Congress, 2nd Session, Doc. 645, Vol. XI. p. 99 (Index B5).

(*d*) 'Changes' and repairs in the apparatus.

DIAGRAM IIIB.—ACCIDENTS IN TEXTILES (LANCASHIRE).

Standard hours of work 6-8, 8.30-12.30, 1.30-5.30.



Lancashire Cotton.
Index—B1.
Illustrates Table IX.A.

Upper Curve :—Total.
Lower Curve :—Women only.

TABLE IX.A.—COTTON TRADE ACCIDENTS.

Quoted from the Report of the Departmental Committee on Accidents 1908.

(1) Figures supplied by the Federation of Master Cotton Spinners' Associations. Refer to 1,750 cases occurring between July 1 and August 5, 1907.
(2) Figures from Report of Chief Inspector of Factories for 1909. Refer to Cotton Spinning Accidents in 1908.
(3) Figures of Mr. Crabtree (an Inspector). Refer to Oldham District (1,000 cases).

Hours of Day	(1) Male.	Fem.	(2) Ages* 13-18	All Ages. Male	Fem.	(1+2) Male.	Fem.	(3) Male and Fem.	Total.
6–7	49	26	52	74	40	123	66	51	240
7–8	128	43	80	138	63	266	106	95	467
8.30–9	90	42	44	56	56	146	98	72	316
9–10	101	43	50	97	61	198	104	70	372
10–11	195	59	105	143	118	338	177	150	665
11–12	168	70	103	134	117	302	187	134	623
12–12.30	173	65	122	152	146	325	211	115	651
1.30–2	86	24	28	50	16	136	40	46	222
2–3	102	36	62	80	57	182	95	60	335
3–4	176	31	86	121	74	297	105	134	536
4–5	143	58	81	111	72	254	130	128	512
5–5.30	161	48	112	168	82	329	130	156	615

NOTES.

The number of accidents given in the Report as occurring between 8–9, 12–1, 1–2, and 5–6 is doubled to allow for the meal-times, which, as the Report of the Committee itself states, take place from 8–8.30, 12.30–1.30, and 5.30–6.

12–5.30 accidents are multiplied by 6/5 to allow for Saturdays, except in (2) where Saturdays not included.

* Full Timers.

TABLE IX.B.—FOUNDRY AND ENGINEERING TRADE ACCIDENTS.

Iron and Steel Foundries	in 1912.
Automotor and Locomotive Mfg.	in 1911.
Shipbuilding	in 1910.

The figures are quoted from the Tables in the Annual Reports of the Chief Inspector of Factories referring to Accidents occurring from Monday to Friday, and reportable either to the Inspector only or to the certifying Surgeons and Inspectors. These tables class accidents according (1) to time of day when they occurred; (2) the working hour 'round' which they occurred (*e.g.*, eighth hour would include accidents occurring after 7½ hours work and before 8½ hours work).

These figures do not attempt to give the number of accidents per number employed at each hour. Hours where few are working owing to meal-times or short-time are compared with full working hours when accidents will *ipso facto* be more frequent.

The following corrections must therefore be made:

(1) Omit all hours where factories may not be working full. Now, where England, Scotland and Ireland are all combined, the start may be any time from 6 to 8, breakfast from 8 to 10, dinner from 12 to 2, and the stop from 5 onwards. This leaves only the hours from 10–11, 11–12, 2–3, 3–4, 4–5 as worth considering among the time of day figures. Among the working-time figures, the occurrence of meal-times is almost incalculable. The following plan, however, escapes uncertainties.

If the working hours be divided into: A, the first half-hour and next hour, and B, the second to the eighth, and C, the ninth hour, it is certain that C will consist (see Note) of one full working hour, A of one and a half full working hours, and B of five and a half working hours where the 'two-break' system is worked, of six where there is one break only (B = seven hours—one hour for dinner only or one hour and a

half for dinner and breakfast). To reckon the average per hour in each period, therefore, A will be divided by one and a half and B by six to five and a half (say, 5½).

In times of depression dismissal of hands or weekly rotation of hands is resorted to in these trades rather than short-time every day. No ' correction ' need be made for this factor therefore.

(2) Omit all accidents due to work which is regularly performed in one part of the day and not another, and is of special danger. This applies to casting in foundries which causes the accidents from molten metal reportable to Inspectors and Surgeons. In foundries, therefore, accidents reported to Inspectors only will be quoted.

Note.—Unless work begins after 7.30, as in Manchester district, on Mondays

TABLE IX.B.

I. NUMBER OF ACCIDENTS IN ALL PROCESSES.

Hour of Day.	Probable Working Hour of Day (D) of Spell (S).	(1) Ship-building.	(2) Loco Mfg.	(3) Auto Mfg.	(1+2+3) Engineering.	(4) Iron and Steel Foundries.
10–11	D4 S2	365	444	84	893	261
11–12	D5 S3	360	544	105	1009	337
2–3	D7 S1	239	230	66	535	171
3–4	D8 S2	345	429	111	885	276
4–5	D9 S3	324	464	99	887	312

II. AVERAGE ACCIDENTS PER HOUR IN ALL PROCESSES.

For All Ages.

Hour of Work.						
A ½th+1st	Per hour	208	250	72	530	184
B 2nd–8th	Per hour	294	380	85	759	256
	% of A	141%	152%	118%	143%	140%
C 9th	Per hour	298	395	95	788	281
	% of A	143%	158%	132%	149%	153%

Ages 13–18 years.

A ½th+1st	Per hour	32	50	10	92	28
B 2nd–8th	Per hour	41	79	20	140	47
	% of A	128%	158%	200%	153%	168%
C 9th	Per hour	41	74	20	135	55
	% of A	128%	148%	200%	147%	196%

TABLE IX.C.—METAL WORKING ACCIDENTS.

The tables in the Annual Reports which correlate causation of accident with the hour of day, though generally denoting by ' causation ' the description of the occurrence (*e.g.*, explosions, catching of finger, &c.) rather than the conditions of the work, yet class together in Shipbuilding, Auto and Loco Manufacture, all accidents occurring on Metal Working Machines. When full hours are certainly worked, the accidents occurred as follows :—

Accidents on Metal Working Machines only.

Hour of Day	Shipbuilding	Auto Mfg	Loco Mfg.	Total
10–11	87	23	80	190
11–12	79	28	103	210
2–3	60	18	50	128
3–4	71	39	66	176
4–5	77	35	108	220

TABLE IX.D.—ACCIDENTS ON EACH DAY OF THE WEEK.

U.K. Chief Factory Inspectors' Reports, 1909, 1910, 1911, 1912.

Cotton Spinning (1908)	Mon.	Tues.	Wed.	Thurs.	Frid.
Men	197*	204	214	232	264
Women	116*	131	136	151	218
(Ages 13–18 (full timers)	131*	132	140	157	233)
Foundries (1912)	1,031	1,130	1,124	1,052	1,152
Shipbuilding (1910)	570	592	579	534	543
Loco Mfg. (1911)	745	823	806	767	745
Auto Mfg. (1911)	193	181	166	207	194
Five industries	2,812	3,061	3,025	2,943	3,116

* *Note.*—In records of the accidents occurring on each day of the week, the most important consideration in modification of the actual figures is the extent to which short-time or over-time prevailed regularly on some days of the week and not on others. Now, in the year in which the accidents of each industry were recorded the Reports themselves tell us, quoting the *Labour Gazette*, that there was a good deal of unemployment (*i.e.*, involuntary idleness), indicating trade depression. This was especially the case with cotton in July, August, and October 1909, and at the Crewe Locomotive Works in 1911; but only in the former was there regularly less work on one day (Monday).

TABLE X.—ACCIDENTS.

Conditions of Employment in the Iron and Steel Industry.

U.S. Senate, 62nd Congress, 1st Session, Doc. 110.

Times of Work of each spell: 6 A.M.–6 P.M., 6 P.M.–6 A.M.
No breaks for meals in Departments 1, 2, and 3.

Workers: All men.

ACCIDENTS.

Day Spell.

Hours of Day	(1) Blast Furnace	(2) Steel-making	(3) Rolling Mills	(4) Mechanical	(5) Yards	All Iron and Steel Plants	
6–7	100	90	147	36	61	712	
7–8	209	116	153	160	165	1587	
8–9	238	138	317	224	209	1944	
9–10	235	152	353	245	231	2242	
10–11	210	167	312	236	188	1981	
11–12	131	100	209	130	116	1268	
12–1	129	75	162	105	82	1003	
1–2	224	142	327	221	184	1875	
2–3	226	147	320	243	201	2042	
3–4	239	141	304	197	198	1900	
4–5	171	116	235	175	133	1462	
5–6	89	80	175	74	77	838	
Night Spell.							
6–7	92	86	187	47	49	746	Mechanics repairing on over-time.
7–8	87	99	188	46	82	833	
8–9	104	105	178	47	69	827	
9–10	121	83	165	54	70	782	
10–11	93	79	191	31	65	739	
11–12	79	64	128	27	49	538	
12–1	65	69	97	26	25	500	
1–2	61	97	155	26	59	648	
2–3	112	84	146	33	63	662	
3–4	85	73	104	23	49	581	
4–5	79	66	116	28	49	555	
5–6	87	76	133	17	41	524	

TABLE XI.A.—ACCIDENTS.

Massachusetts.—Report of Industrial Accident Board.

Total Industry and Building, Metals and Textiles.

A. July–June 1912–13, Fatal and Non-Fatal Accidents incapacitating 1 day.

B. July–June 1913–14, Non-Fatal Accidents only (yet unpublished).

Times of Work.—Mfg. 6.45 or 7–12, 12.50 or 1 to 5.30. Saturday half-holiday often.

	Bldg. 8–12, 1–5.		Do.			Do.	always.
	Building and Hand Trades A.	Metal and Foundries A.	Wool A.	Cotton A.	Cotton B.	Total Industry, including Stores A.	Total Industry, including Stores B.
Wkly. no. of hrs.	44–48	54	56	56	56		
Men's cases %	100%	99%	80%	77%	—	91·5%	
6.30–7.30	70	138	138	324	319	2,130	2,220
7.30–8.30	375	476	243	632	648	5,869	6,376
8.30–9.30	739	687	364	824	833	8,655	9,203
9.30–10.30	1,174	879	494	1,040	1,168	11,857	12,940
10.30–11.30	1,008	851	386	996	971	10,956	12,204
11.30–12.00	(*b*) (1,160)	(832)	(418)	(856)	(1,908)	(12,040	(12,918)
12–1 or 12.45			Lunch.				
? 1.30	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)
1.30–2.30	773	518	214	530	532	7,245	7,852
2.30–3.30	996	766	331	825	738	10,035	10,440
3.30–4.30	789	913	348	716	776(*a*)	9,171	9,776(*a*)
4.30–5.30	388	680	303	640	652(*a*)	6,959	7,225(*a*)
Day of Week							
Monday	1,386	1,281	586	1,342	—	6,381	16,463
Tuesday	1,346	1,185	587	1,301	—	15,555	16,690
Wednesday	1,260	1,164	587	1,273	—	14,947	16,600
Thursday	1,170	1,167	578	1,297	—	15,093	16,045
Friday	1,213	1,234	651	1,400	—	15,371	16,653

NOTES.

(*a*) Children, 4% or less of workers, leave at 4 or 5. 8 hour day introduced October 1913.

(*b*) Rate per hour. Figures multiplied by 2.

(*c*) Actual figures not averageable.

TABLE XI.B.—ACCIDENTS.

Massachusetts, July 1912–*June* 1913.—*Report of Industrial Accident Board.*

Separate Industries with hourly max. of at least 100 accidents.
Fatal and all non-fatal accidents causing over one day's absence.
Working Times (General) 6.45–12, 1–4 or 5.

Work	Tannery	Gas-Works	Rubber	Paper	Print. & Pub.	Elect. Supp.	Autos	Shoes
Wkly no. of hrs.	55–59	48(*b*)	?	60	48 & 42	48(*b*)	54	54
Men's cases %	98%	100%	92%	91·5%	88%	97%	100%	82·5%
6.30–7.30	32	16	51	21	6	101	14	85
7.30–8.30	56	47	126	71	25	324	39	331
8.30–9.30	89	91	187	124	49	412	79	490
9.30–10.30	116	133	242	160	92	527	107	716
10.30–11.30	107	136	220	125	103	470	99	573
11.30–12 (*a*)	(88)	(120)	(264)	(168)	(154)	(506)	(84)	(662)
12–1 or 12.45			Lunch.					
? –1.30	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)
1.30–2.30	59	94	148	86	81	296	70	394
2.30–3.30	87	105	211	128	94	442	103	539
3.30–4.30	105	89	189	85	79	390	89	497
4.30–5.30	74	72	169	92	67	355	72	268
Monday	152	168	356	215	135	766	135	832
Tuesday	147	151	369	189	113	758	145	827
Wednesday	138	139	337	210	158	717	120	802
Thursday	152	168	323	195	133	748	126	788
Friday	171	166	352	198	140	680	154	745

NOTES.

(*a*) Rate per hour. Actual figures doubled.

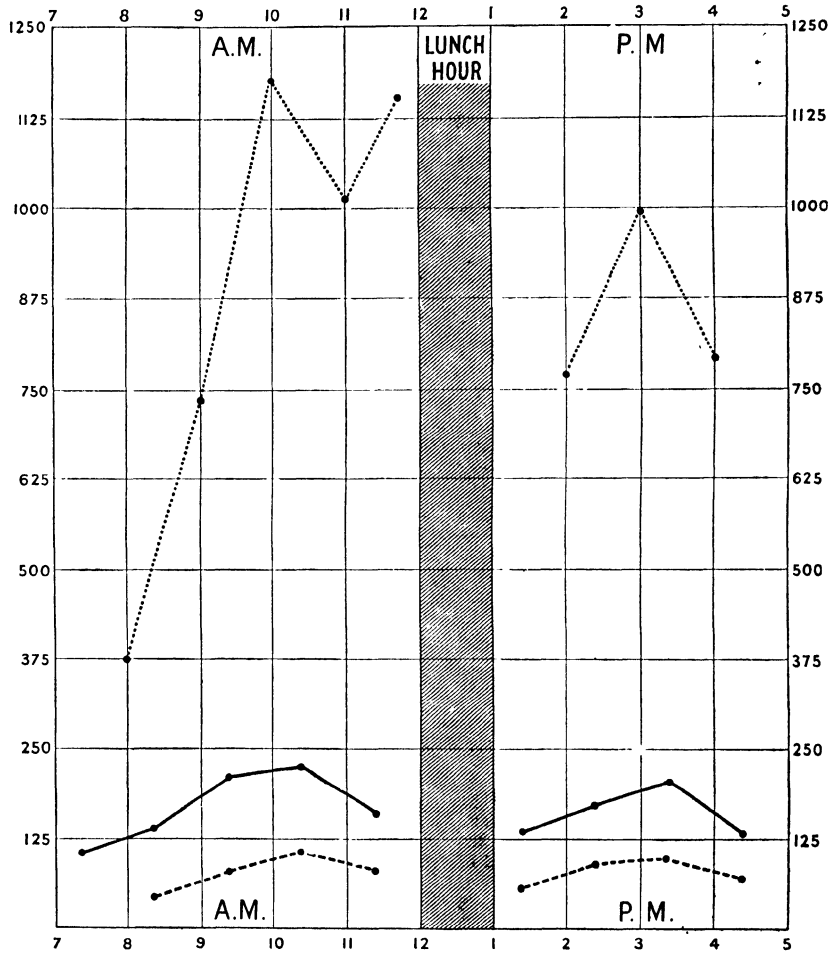
(*b*) Stokers have 56-hour week or more.

(*c*) Actual figures not averageable.

Underlined are the spell-maxima for each industry.

*

DIAGRAM IV.—ACCIDENTS IN BUILDING.
Hours of work usually 8 per day, starting



Index No.: B8. *Cf.* Table XII. B7. — B9. *Cf.* Table XI.A.

TABLE XII.—ACCIDENTS.

Ohio: *Jan.* 1–*June* 30, 1914, *Industrial Commission, Dept. of Investigation Report No.* 4.

All accidents involving disability for one day or more.
Workers.—Total Industry. All men, except in 512 cases women.
Times of Work.—See Note (*a*). Coal: 8-hour shift usually.
Work.—All trades having hourly maximum of over 100 accidents.

	Contracting (Building).	Metals.	Coaches.	Coal Mining.	Pottery Glass.	Industry Total.
No. of hrs. weekly.			60–54		60–50	
7– 7.59 . .	104	736	74	51	71	1,478
8– 8.59 . .	142	953	115	100	97	2,043
9– 9 59 . .	210	1,296	151	140	106	2,768
10–10.59 . .	222	1,291	182	150	126	2,997
11–11.59 (*a*) .	(158)	(973)	(129)	(120)	(71)	2,106
12–12.59			Lunch.			
1– 1.59 . .	135	724	63	92	72	1,586
2– 2.59 . .	174	1,057	102	137	118	2,317
3– 3 59 . .	202	1,351	165	106	87	2,746
4– 4 59 . .	136	1,155	119	(28)	79	2,161
Day of Week.						
Monday . .	321	2,268	229	204	177	4,632
Tuesday . .	269	2,224	214	194	199	4,522
Wednesday .	288	2,187	223	165	171	4,388
Thursday . .	283	2,215	218	184	172	4,436
Friday . .	279	2,197	224	165	192	4,377

NOTES.

(*a*) Quoted from Report, page 31 (see above).

'Data are not available showing the number of men exposed to accidents, but there is no great variance during the period from 7.30–11.30 in the forenoon and from 1 to 5 in the afternoon.' The uncertainty from 11–12 is due to the main industries of Ohio being on the border of Central and Eastern time.

TABLE XIII.—ACCIDENTS.

Illinois.—Manufactures, excluding Contracting, but including Lighting, Posts and Laundries.

All accidents causing one day's absence.
Usual working hours: 7–12 (few 11.30), 1 or 12.30–5.

Bureau of Labour Statistics Report.

	1911 (Jan.-Dec.)	1912 (May-Dec.)	1913 (Jan.-June)	Total	1911-1913 Women	1911-1913 All under 18	Bogardus 1910
7– 7.59 .	160	302	233	695	5	16	79
8– 8.59 .	231	422	317	970	28	29	150
9– 9.59 .	272	549	454	1,275	29	30	193
10–10.59 .	286	661	538	1,485	41	40	246
11–11.59 .	283	662	493	1,438	41	42	257
12–12.59			Lunch.				
1– 1.59 .	178	406	302	886	16	22	111
2– 2.59 .	258	561	434	1,253	28	32	156
3– 3.59 .	269	628	485	1,382	29	38	227
4– 4.59 .	283	590	464	1,337	24	37	260
5– 5.59				736		28	

The Bureau Reports tabulate separately fatal and non-fatal accidents and for 1912 and 1913 accidents compensated under the law, effective May 1, 1912, and those not thus compensated. These separate figures have been added for each year.

Bogardus subtracts all accidents not in any way attributable to human agency (82 per cent.). See Index D7.

TABLE XIV.—ACCIDENTS.

Belgium.—Rapport Manuel de l'Inspection du Travail, 1907, pp. 212-217.

Usual working hours: 6-12, 1-7.

Trades having 400 accidents or over.

	(a) Text.	Build.	Mech.	Wood.	Food.	Chem.	Total Industry.
6- 7	73	18	20	14	24	6	167
7- 8	229	70	50	41	26	37	500
8- 9	(b) (168)	(67)	(65)	(31)	(37)	(31)	(454)
9-10	214	83	86	54	43	41	586
10-11	343	116	105	82	60	43	835
11-12	294	87	84	66	49	39	675
12- 1			Lunch.				
1- 2	48	22	10	12	14	14	136
2- 3	152	62	52	46	35	23	403
3- 4	307	137	105	67	58	44	787
4- 5	(b) (190)	(89)	(56)	(54)	(37)	(33)	(504)
5- 6	216	63	73	70	54	41	568
6- 7	295	49	82	70	47	33	623
Monday	406 (c)	178	139	120	95	64	1,108
Tuesday	454	150	139	118	78	73	1,117
Wednesday	454	159	143	122	86	70	1,129
Thursday	402	150	132	83	101	81	1,051
Friday	418	126	135	101	84	71	1,035
Saturday	524 (d)	164	153	122	105	70	1,261

NOTES.

(a) Of total accidents in textiles, 1,949 occurred to men; 744 to women.
(b) Breaks for meals usually occur in these hours.
(c) Some factories close at 4 on Mondays.
(d) Women and boys cleaning machinery in motion.

TABLE XV.—ACCIDENTS.

Germany.—Amtliche Nachrichten des Reichsversicherungsamts.

A.—Industry in 1887 (a). B.—Agriculture in 1891.

Austria.—C. General Workman's Sickness and Relief Insurance, Vienna (b).

Usual hours (Würtemberg) { Total pauses. 1-3 hrs. 1-1½ at noon.
50 per cent have Sat. half-holiday.
6 or 7 A.M.-6 or 7 P.M.

France (D.).—Imbert in *Revue Scientifique*, Oct. 21, 1905. All Industries. Hours certainly worked full 7-11 A.M., 2-5 P.M. (M. Le Roy.)

	A.	B.	C.	D.	
(6-7)	(511)	(435)	(187)	At 6,	110
7- 8	747	794	437	At 7,	232
8- 9	1,126	815	517	At 8,	305
9-10	1,421	1,069	716	At 9,	340
10-11	1,857	1,598	505 Pause.	At 10,	478
11-12	1,623	1,590	338	At 11,	292
12- 1			Lunch		
1- 2	982	745	331	At 1,	132
2- 3	1,408	1,037	538	At 2,	310
3- 4	1,986	1,243	700	At 3,	421
4- 5	2,016	1,178	508 Pause.	At 4,	588
5- 6	1,518	1,306	418	At 5,	513

NOTES.

(a) The accidents in 1897 and 1907 have unfortunately been grouped into 3-hour periods during which the number of men fully at work is undiscoverable. (See *U.S. Labour Bulletin* 92.)

(b) Goldmark, Part II. of larger edition, p. 205.

TABLE XVI.—ACCIDENTS.

	Industrial Commission, Wisconsin. Jan. 1913–June 1914.	*Amtliche Nachrichten des Reichsversicherungsamts*, 1910. *Germany.* 1907.
Times of Work:	7–12, 1–5 or 6.	6 or 7–12, 1–6 or 7. Break at 4.
Hour of Work.		
1st	737	3,933
2nd	1,030	6,885
3rd	1,692	7,351
4th	1,805	9.004
5th	1,608	9,739
6th	1,298	8,106
7th	1,334	6,462
8th	1,475	6,903
9th	1,546	6,817
10th	1,216	6,041
10 and over	459	8,530

Note.—American and German working times being less broken up by breakfast breaks than English (Section V.A), it is quite worth while reproducing these two attempts that have been made to record the accidents recurring in each '*working hour*' as distinguished from the clock-hour.

In the Wisconsin figures (not yet published) the meal-hour, 12–1, has been subtracted from all the afternoon hours, in the German it would be included in the later ordinals.

TABLE XVII.—*Accidents in the Manufacture of Driving Chains and Engineering.*

Hans Renold. Burnage, Manchester.

Range.—Whole factory except Depts. 7 and 35, from Nov. 1910 to April 1914. Owing to changes in the factory hours, Monday accidents are omitted in 1910–1912. Saturday accidents from Nov. 1910 to May 1912 and all accidents in Dept. 2 from May 1912 to April 1914.

Accident.—Covers all cases requiring first aid and reported to the matron in attendance at factory.

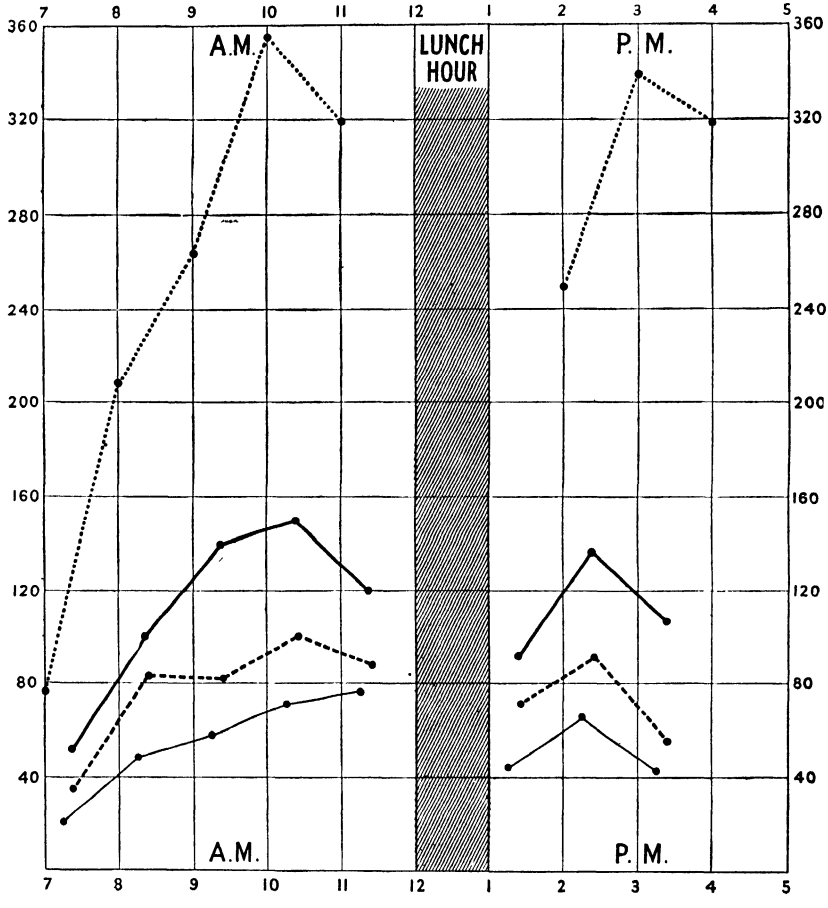
Hours of Day.			Four Winters. Nov.–April 1910–14.	Three Summers. May–Oct. 1911-14.	Total.
8– 9	D1	S1	151	121	272
9–10	D2	S2	168	153	321
10–11	D3	S3	169	195	364
11–12	D4	S4	197	178	375
12– 1	D5	S5	147	105	252
2– 3	D6	S1	176	159	335
3– 4	D7	S2	177	195	372
4– 5	D8	S3	181	158	339
5– 6	C9	S4	124	182	306

Corrections made.—(i) Where Saturdays are not omitted (see above), the afternoons (from 12 on in 1912 from 12.15 in 1913–14) are averaged by multiplying all afternoon figures by 6/5.

(ii) From Jan. 1, 1913, work stops at 5.45; figures for 5–6 after that date are multiplied by 4/3.

DIAGRAM V.--ACCIDENTS IN MINING.

Hours of work usually 8 per day; starting early.



	Ohio (Coal)	Illinois (Coal)	Minnesota (Iron)	Washington (Coal)
Index No.:	B8	B7 (1912–13)	B10	B11
Cf. Table XII.		—	—	–

*

TABLE XVIII.—CHOCOLATE-MAKING ACCIDENTS.

Cadbury Bros., Bournville.

Range.—Whole of factory that is working at the hours specified below during the years 1909 to 1914 inclusive.

Accident.—Covers all cases requiring 'first-aid' and reported to the factory medical staff.

*Rates of Accidents per Hour.**

Girls.			Men and Boys.			
Starting at 8.	Starting at 9.		Starting at 6 with two breaks.		Starting at 7.45.	
			6 – 6.30	22*		
			6.30– 7.30	50		
			7.30– 8.30	49		
8– 9	21				7.45–8.30	53*
9–10	19	23	9 – 9.30	38*	8 30–9.30	52
10–11	28	13	9.30–10.30	54		85
11–12	26	17	10.30–11.30	73		96
12–12.30	38*	26*	11.30–12.30	70		92
1.30–2	14*†	22*†	1.30– 2 A.M.	27*†	1.30–2.30	50†
2– 3	14†	24†	2 – 3	59†	2.30–3.30	83†
3– 4	24†	12†	3 – 4	73†	3.30–4.30	84†
4– 5	24†	20†			4.30–5.30	90†
5– 5.30	41*	17*†				

* All figures are averaged up to the hour.

† All afternoon figures are multiplied by 6/5 to allow for Saturday afternoon off. Other afternoons are also taken off occasionally, so that for comparison with the morning figures some further addition should be made.

TABLE XIX.—ACCIDENTS.

National Cash Register, Dayton, Ohio.

1914 and 1915 till April.

Hours of Work.

'Full.'—Till August 1914: 6.30–12; 1–5.15. Sats till 11.45.
'Short.'—After August 1914: 7–12; 1–4.30. No Saturday work.

Wages.—Piece rates.

6.45–7.44	151*	12.45–1.44	141*
7.45–8.44	180	1.45–2.44	197*
8.45–9.44	259	2.45–3.44	273*
9.45–10.44	308	3.45–4.44	261*
10.45–11.44	181		

* *Note.*—All short time and Saturday afternoons have been 'averaged.'

TABLE XX.—ACCIDENTS.

Cadillac Motor Company, Detroit, Mich.

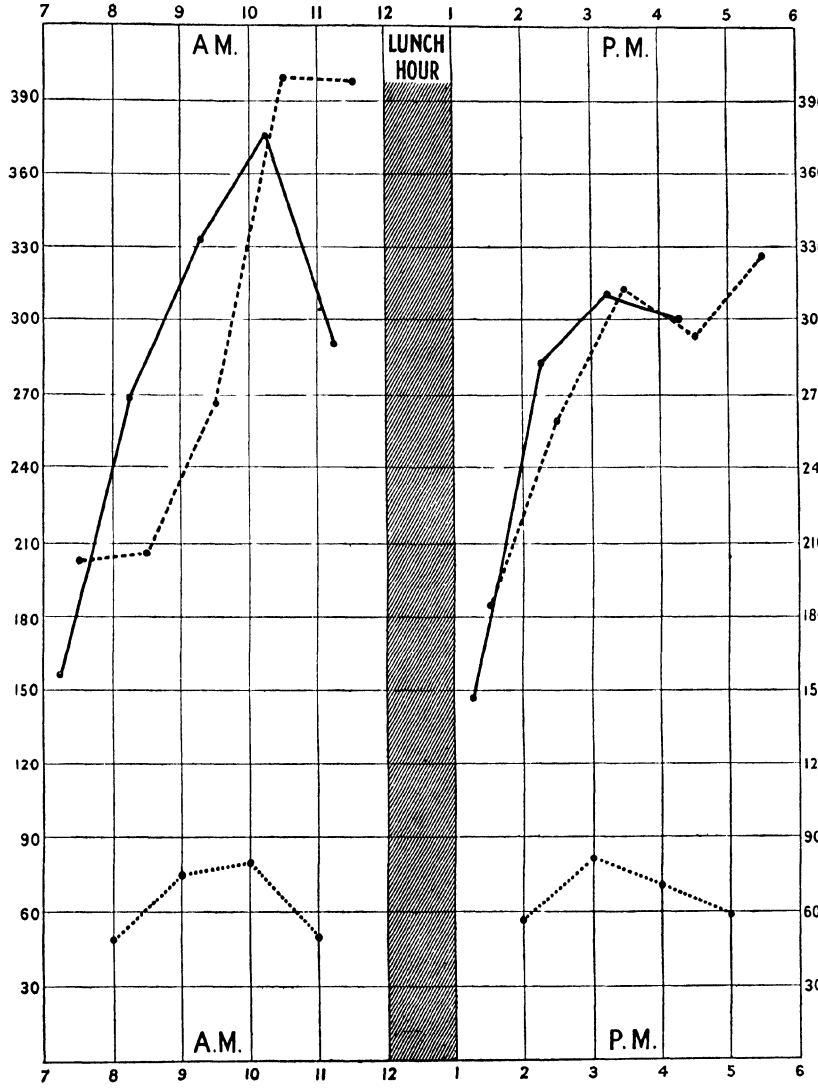
9 months up to January 1914.

Hours of Work.—6.30–11.30; 12.30–5.30. Sat. till 11.30.
Workers.—All men.

6.30–7.30	107	12.30–1.30	125*
7.30–8.30	130	1.30–2.30	172*
8.30–9.30	129	2.30–3.30	200*
9.30–10.30	152	3.30–4.30	116*
10.30–11.30	88	4.30–5.30	94*

* *Note.*—Afternoon figures include an average for Saturday.

DIAGRAM VI.—AGRICULTURE*; LUMBERING† (60-hour week)



Index:	B11.	B10.	B4.
	—	—	*Cf.* Table XV.‡

‡ Actual number of Accidents divided by four to bring them within the scope of the notation.

TABLE XXI.—ACCIDENTS.

Ford Motor Co., Detroit, Mich.

1913 and 1914.

Hours of Work.—6.30 or 7–12 or 11.30; 12 30 or 12–3 or 3.30.
(Eight-hour day for six days a week.)

Workers.—Mostly men.

Hour of Day		Hour of Day	
6.30–7.29	136		
7.30–8.29	232	12.30–1.29	171
8.30–9.29	272	1.30–2 30	300
9.30–10.29	276		
10.30–11.29	210		

TABLE XXII.—ACCIDENTS.

Northway Motor and Manufacturing Co., Detroit, Mich.

Jan.–May 1915.

Hours of Work.—6.30–11.30; 12–5. Sat. till 11.30.

Hours of Day		Hours of Day	
6.30– 7	58 per hour	12–1	25
7 – 8	101	1–2	89
8 – 9	86	2–3	101
9 –10	99	3–4	119
10 –11	106	4–5	154
11 –11.30	88 per hour		

Note.—Afternoon figures include an average for Saturday.

TABLE XXIII.—ACCIDENTS.

Denison Manufacturing Co., Framingham, Mass.

Hours.—April to October: 7.40–12; 1–6; Sats. quit 12.
Nov. ,, March : 7.45–12; 1–5.30; Sats. quit 4.
Work.—Cardboard-boxes, labels, fancy paper.
Worker.—5 women to 3 men (machinists).

7.30– 8.30	26	1.00–1.30	34
8.30– 9.30	34	1.30–2.30	36
9.30–10.30	55	2 30–3.30	42
10.30–11 30	36	3.30–4.30	35
11 30–12.00	40*	4.30–5 30	33

* Rate per hour.

TABLE XXIV.—ACCIDENTS.

Jacob & Co., Biscuit Mfg., Dublin.

1913 and 1914 (Jan.–Nov.).

Hours.—8–1; 2–6.
Workers.—Mainly Girls.

	1913	1914		1913	1914
8– 9	15	17	2–3	21	7
9–10		12	3–4		12
10–11	25	4	4–5	25	18
11–12		18	5–6		15
12– 1	22	19			
Lunch time		5			

Section VII.—Index of Documents and Books Quoted.

A.

Goldmark, Josephine, Russel Sage Foundation. 'Fatigue and Efficiency.' Large edition with Part II., 'The substance of four briefs.' Charities Publication Committee, New York, 1912. Besides the advocacy of practical legislative reforms, Miss Goldmark gives admirable summaries of all records, experiments, and investigations of the economic effects of fatigue, many references to which are made below.

B. *Records.*

B1. *United Kingdom.* Departmental Committee on Accidents, 1911. Cd. 5540. Among the *Minutes of Evidence* the following relate positively and authoritatively to the question of fatigue. 9485–9512 Mr Knott gives number of accidents in the Dyeing and Bleaching Industry for periods 9 A M–1 P M, 1 P M–4 P M., and two halves of the week, and explains their features on the basis of fatigue and anticipatory excitement. 13180 ff., 5803 ff. . . . The influence of long hours and night work is discussed in increasing the rate of accident through fatigue Individual cases are cited, particularly of young persons. In the Report itself are given all the accident time-distributions for the Cotton Industry quoted in Table IX.A and Diagram II, and fatigue is discussed on page 15; but since it was the alarming increase of accidents *from year to year* that called the Committee the daily or weekly curve does not occupy them.

B2. *United Kingdom.*—Chief Factory Inspectors' Reports. Contain studies of accident time-distribution in selected industries, as follows:—

1909. Cotton Industry.
1910. Shipbuilding.
1911. Automotor and Locomotive Manufacture.
1912. Iron and Steel Foundries.

Quoted Tables IX. A, B, C, D

B3. *Belgium.*—Rapports Annuels de l'Inspection du Travail, 1907. Page 204 gives charts showing the number of accidents in the district of Ghent for each hour of each day of the week. See Goldmark, Part II. (p 202). Quoted Table XIV.

B4. *Germany.*—Imperial Insurance Department. U.S. Bureau of Labour Bulletin No. 92, 'Industrial Accidents in Germany,' summarises the decennial 'Amtliche Nachrichten des Reichsversicherungsamts' for 1897 and 1907, quoted Table XVI. U.S. Commissioner of Labour, 24th Annual Report, summarises the 'Nachrichten' for 1890, quoted Table XV.

B5. *U.S. Senate.*—61st Congress, 2nd Session, Doc 645, Women and Child Wage-earners.—Vol. XI., p. 99, gives accident and output time distributions among press hands and in the metal trade generally (quoted Diagram II. and Table VIII. respectively), and compares these with the accident-distribution in the cotton industry (quoted Diagram III.) and manufactures generally, in the States of Wisconsin and Indiana (quoted Diagram I.).

B6. *U.S. Senate.*—62nd Congress, 1st Session, Doc. 110.—'Conditions of Employment in the Iron and Steel Industry.' Vol. IV. gives accident and output time-distribution. Quoted Tables X. and VIII.

B7. *Illinois.*—Bureau of Labour Statistics Reports: Industrial Accidents, 1911, 1912, 1913. Quoted Table XIII. and Diagram I.

B8. *Massachusetts.*—Industrial Accident Board Report (1st), 1912–13. Quoted Tables XI. A and B, and Diagrams II. and IV.

B9. *Minnesota.*—Bureau of Labour 12th Annual Report. Gives number of accidents for each hour of day and night in Lumbering, Mining, and Manufactures separately Quoted Diagrams I., V., and VI.

B10. *Ohio.*—Industrial Commission Dept. of Investigation and Statistics Report: No. 4, 'Industrial Accidents, 1914.' Quoted Table XII. and Diagrams IV, and V.

B11. *Washington.*—Industrial Commission Reports. Give number of accidents for every half-hour of day. Greater proportion occur in 'Lumbering' classed separately in 1912, under Industry in 1913. Quoted Diagram VI.

B12. *Wisconsin.*—Bureau of Labour and Industrial Statistics. Fourteenth Biennial Report, 1909–10. Gives hourly distribution of manufacturing accidents. Quoted B5 and Diagram I.

C. *Experiments in Factory Organisation.*

C1. Roth, Emil, 'Ermüdung durch Berufsarbeit.' Fourteenth International Congress of Hygiene and Demography. Contains a comparison of the amount of electrical current used at Siemens and Halske before and after a change in organisation. When the hours of work were 7–8.30, 9–12, 2–4 and 4.30–6, and the worker brought his own food, there was a slow increase by practice, a maximum at 9.30–11.30, a fast falling off and less current in the afternoon than morning. When the hours of work were 7–8.30, 9–12, 12.30–2.30, 3–4.30, and food was provided, there was a fast increase by practice, a maximum at 9.15–11.45, little falling off, and current almost as high in the afternoon. Roth is careful to point out that a stricter discipline was enforced after the change that may explain some of the increase of current.

C2. Fromont, L. G., at the Engis Chemical Works, Liège, 'Une Expérience Industrielle de Réduction de la Journée de Travail.' Results on output and sickness of a reduction of hours; for a summary see Goldmark, p. 63.

C3. Mather, Wm., M.P., 'The Forty eight Hours Week: a year's experiment and its results at the Salford Iron Works.' Published in pamphlet form, Manchester, 1894. Gives comparison of wages-cost, lost time, and piecework before and after change from fifty-three to forty-eight hour week. For Summary refer to Goldmark, Part I., p. 138.

C4. 'Board of Trade Labour Gazette,' July 1905. Describes 'Reduction of hours in Government Factories and Workshops.' An average reduction of $5\frac{3}{4}$ hours per week in work-places under the War Office and an average reduction of $2\frac{1}{2}$ hours per week in work-places under the Admiralty, reducing both to a 48-hour week and introduced in 1894. The output remained the same.

C5. The Twelve-Hour Shift in the Steel Foundry. R. A. Bull, 'Iron Age,' Oct. 3, 1912. Compares in detail the materials spent and the quality and quantity of the product before and after a change from the 12-hour to the 8-hour shift at the Commonwealth Steel Co., Granite City, Ill. 'The differences in most cases are slight, but the essential ones are in favour of the short shift.' 'The comparison indicates fully a more economical and efficient manipulation of both open-hearth and boiler furnaces.'

C6. United States Bureau of Labour Bulletin No. 118, 'Ten-Hour Maximum Working-Day for Women and Young Persons.' On page 46 figures are given to show that in three factories in Calcutta where the numbers of hours worked were *increased* from $11\frac{1}{2}$ to $13\frac{1}{2}$ up to $14\frac{1}{2}$, there was a decrease of output as follows:—

Hours per Day Production in	Per cent. of Production in 1906 over 1907 Factory 1	Factory 2	Factory 3
$13\frac{1}{2}$ hours work . . over $14\frac{1}{2}$ work	8·87	15·85	4·49
$13\frac{1}{4}$,, ,, . . ,, ,,	17·32	26·54	5·04
13 ,, ,, . . ,, ,,	9·14	22·19	4·56
$12\frac{1}{2}$,, ,, . . ,, ,,	—	—	10·96
$12\frac{1}{4}$,, ,, . . ,, ,,	12·08	19·21	—
12 ,, ,, . . ,, ,,	10·09	15·65	5·68
$11\frac{1}{2}$,, ,, . . ,, ,,	4·61	9·36	17·17

C7. Associated Efficiency Engineers, New York, 1914, 'Efficiency Study of a Mill's Work.' This pamphlet 'examines the expediency of operating only five days a week, with a shutdown on Saturday for cleaning up and mill repairs.' It finds that the average tonnage per month under this 'five-day basis' was only 2·3 per cent. below that attained on the six-day basis, the total manufacturing or 'conversion' cost 1·8 per cent. below and the 'conversion' cost per ton ·3 per cent. above; there is less depreciation on plant and increased efficiency from men and equipment.

C8. Abbé, Ernst, 'Die Volkswirtschaftliche Bedeutung der Verkurzung des Industriellen Arbeitstages.' Published in 'Gesammelte Abhandlungen,' Part 3, Jena, 1901. Lecture I. compares the output and use of power in the Zeiss Optical Works, Jena, for four weeks under a nine-hour day system and for four weeks after the change to an eight-hour day in 1900. For summary refer to Goldmark, Part I., p. 155.

D. *Investigations (Special Correlations).*

D1. Huntingdon, Prof. Ellsworth, 'Work and Weather.' *Harper's Magazine*, January 1915, p. 233. A summary is given in Section I.B.

D2. Imbert, Prof. A., 'Les Accidents du Travail et les Compagnies d'Assurances.' *Revue Scientifique*, June 4, 1904, p. 715. Gives the daily-curve time of 660 accidents in transport and manufacture combined in 1903. See Goldmark, Part II., p. 193.

D3. Imbert, Prof A , and M. Mestre, 'Statistique d'Accidents du Travail.' *Revue Scientifique*, Sept. 24, 1904. Gives diagrams illustrating the *daily* accident time-curve:

A, For 660 Accidents in transportation, 326 in chemical works, and 189 in wood-working in the Dept. of Hérault, 1903.

B, For 280 Accidents in building, etc , 149 in metals, and 237 in commerce and banking in the Dept. of Hérault, 1903.

C. For 2,065 accidents in Industry in Dept. of Hérault.
For 5,534 accidents in 9 Depts. of Toulouse district.

D4. Imbert, Prof. A., and M. Mestre, 'Nouvelles Statistiques d'Accidents du Travail,' *Revue Scientifique*, Oct. 21, 1905, p. 521. Gives diagrams illustrating the accident time-curve:

(A) For hours of day of 3,352 accidents in all industries in 5 Departments of Southern France in 1904. Quoted by Bogardus (Index D7). See Goldmark, Part II., p. 198. Quoted Table XV.

(B) For days of week. In Belgian manufactures 1901–2 and 1902–3, and in 2,065 accidents in all industry in Dept. of Hérault, whose hourly occurrence was given in article of Sept. 24, 1904.

D5. Pieraccini, G., 'La Curva della Produzione Utile,' First International Congress on Industrial Diseases, Milan, 1906. Gives some output and mistake time-distributions. For summary refer to Goldmark, Part I., p. 133.

D6. Marsh, Howard D., 'The Diurnal Course of Efficiency.' New York, The Science Press, pp. 99. On pages 33–41 is given the output for each hour of the day in the following operations, all of which Dr. Marsh personally supervised:

1, Eight girls, on piece wage, stitching magazines with wire for an average of eight days and a half with three evenings and a half.

2, Eight girls, on piece and time wage, making paper coin-cases for an average of five days and a half.

3, Six girls, on time wage only, numbering checks and ledger-lines for an average of one day and a third.

Dr. Howard discusses the different effect on output of work requiring speed, accuracy, and strength; of time and piece wages, and of the age of the worker. Being interested primarily in the psychology of the individual, he criticises the 'smoothing' out of curves into types and pays great attention to the deviations of the individual curves from the average.

D7. Bogardus, E. S., 'The Relation of Fatigue to Industrial Accidents.' *American Journal of Sociology*, 1911, pp. 17, 206–222, 351–374.

Bogardus sets himself the following problems, to each of which we append Bogardus's own solution:—

p. 211. (*a*) 'The formulation of a law of the development of the fatigue processes which accompany continued work, in so far as they may be related to accidents.'

(p. 222) 'Uninterrupted muscular activity is accompanied by inaccurate muscular co-ordinations which increase irregularly and at a rate largely determined by the speed and relative difficulty of the activity for the given individual.'

(*b*1) 'In what ways is the development of the fatigue process hastened in the case of present-day working people, and why; and what are the observable circumstances under which these processes result in accidents?'

(p. 301.) 'The chief industrial conditions leading up to and culminating in accidents are those of monotony and speed and of unrelaxed tension kept up for long hours.'

(*b*2) What are the concrete immediate conditions preceding accidents—The *modus operandi* of the general causes in bringing about accidents?'

'Of 2,666 accidents in Illinois, 1910, 17½ per cent. (463) were beyond control of the injured; 82½ per cent. (2,203) avoidable by injured.'

(*c*) 'Can the subjective fatigue processes be measured by means of controlled experiments in terms comparable to the observable conditions preceding accidents and thus be causally related to accidents?'

In answer to this problem Bogardus invented an experimental instrument that seems to produce the actual conditions of industry extremely successfully.

(*d*) To test his theories 'objectively' Bogardus then examines the hour at which those accidents in Illinois which were 'avoidable by the injured' (see above) occurred; this hourly distribution is quoted in Table XIII., Col. 7, of our Report. With these figures Bogardus then compares the similar accident time-distributions compiled in Germany (Index B4, Agriculture in 1891, and Industry in 1887), France (Index D4), Belgium (Index B3), Wisconsin (Index B12), and in American Cotton Industries (Index B5), finally adding up all the accidents figuring at the same hour of day. Such a comparison and 'summing up' of different countries, authorities, and industries seem to us somewhat arbitrary, since each of the countries and some of the industries (*e.g.* Agriculture) have different working hours and many of the authorities have adopted different plans of delimiting the hour.

(*e*) 'To what extent do investigations of the causes of railway accidents, for example, by the Interstate Commerce Commission isolate fatigue as a cause of accidents, and have the Courts indicted fatigue as a cause of accidents?'

In answer, some findings of the Courts are cited.

Bogardus then advocates certain legislative and management reforms, and summarises his conclusions as follows:—

The typical succession of events consists in:—

(*a*) The development of fatigue.

(*b*) The development of muscular inactivities due to this increasing fatigue.

(*c*) Increasing number of accidents due immediately to this increasing loss of muscular accuracy.

D8. Weber, Max, 'Zur Psychophysik der industriellen Arbeit,' in the 'Archiv fur Sozialwissenschaft und Sozialpolitik.'

Articles. I. Vol 27 (1908), pp. 730 ff.
II. and III. Vol. 28 (1909), pp. 219–277 and pp. 719–761.
IV. Vol. 29 (1909), pp. 513–542.

These articles by Weber fall into two parts; the first part, consisting of the first article and the beginning of the second, is an attempt to view Kraepelin's psychological study of fatigue from the economic standpoint, and has been translated in full for the Committee by Mr. C. K. Ogden.

In the second part Weber has, to quote his own words, 'given an illustration of how the figures are to be handled' (p. 241, 2nd article), so as to throw further light on the conclusions of Kraepelin, especially in regard to the following points:

1. The facts about the output curve and its most important determinants,
2. The analysis of the curve according to each of its component factors,

and also so as to suggest further conclusions, and finally to attempt to trace 'how far differences in workers' output is due to inherited ability and their cultural, social, and occupational environment.'

With this purpose in view Weber studied the output of a Westphalian cotton-weaving establishment from the indications of registers on the looms, and he presents his records in the following tabulations :—

1. 2nd article, p. 249 :—The daily output of looms on similar work for 30 successive days.
2. ,, ,, 249 :—The daily output of one loom for 25 successive days.
3. ,, ,, 252 :—The output of each day of the week for 100 weeks. (Quoted in Table I. of this Report.)
4. ,, ,, 273 :—A study of different individual workers, specifying their age and working habits, &c.
   (i) Their piece earnings.
   (ii) The daily variation of their output within the week.
   (iii) Their weekly output (average of 6 days).
5. 3rd article, p. 739 :—The length of training required for new kinds of work.
   p. 744 :—The degree of 'increasing stability' acquired by practice.

These Tables, as Weber himself carefully warns us, are not sufficient to establish any conclusion, but are simply given for methodological illustration.

In his fourth and last article Weber traces in great detail all the events occurring within a definite period in the life and work of specified individuals, choosing some women turners (Andreherin) as an example of hand-workers and some weavers as an example of machine-workers, and explaining according to actual occurrences the variations in their output, pay, practice, &c., &c.

Many of the suggestions of Weber have been incorporated in this Report, particularly his enumeration of some of the conditions of fatigue (Section I.).

Prime Numbers. *By* G. H. HARDY, *F.R.S.*

(Ordered by the General Committee to be printed *in extenso*.)

THE Theory of Numbers has always been regarded as one of the most obviously useless branches of Pure Mathematics. The accusation is one against which there is no valid defence; and it is never more just than when directed against the parts of the theory which are more particularly concerned with primes. A science is said to be useful if its development tends to accentuate the existing inequalities in the distribution of wealth, or more directly promotes the destruction of human life. The theory of prime numbers satisfies no such criteria. Those who pursue it will, if they are wise, make no attempt to justify their interest in a subject so trivial and so remote, and will console themselves with the thought that the greatest mathematicians of all ages have found in it a mysterious attraction impossible to resist.

The foundations of the theory were laid by Euclid. Among Euclid's theorems two in particular are of fundamental importance. The first (Euc. vii. 24) is that *if a and b are both prime to c, then ab is also prime to c.* This theorem is the basis of the whole theory of the factorisation of numbers, systematised later by Euler and by Gauss, and in particular of the theorem that *every number can be expressed in one and only one way as a product of primes.* The second theorem (Euc. ix. 20) is that *the number of primes is infinite:* to this theorem I shall return in a moment.

In modern times the theory has developed in two different directions. In the first place there is what may be called roughly the theory of *individual* or *isolated* primes, a theory which it is difficult to define precisely, but of which a general idea may be formed by considering a few of its characteristic problems. How can we determine whether a given number is prime? what conditions are necessary and what sufficient? Can we define forms which represent prime numbers only? Are there infinitely many pairs of primes which differ by 2? Is (as Goldbach asserted) every even number the sum of two primes? This theory I shall dismiss very briefly. We know a number of very beautiful theorems of this character. I need only mention Wilson's theorem, Fermat's theorem, and the extensions of the latter by Lucas. But on the whole the record of research in this direction is a record of failure. The difficulties are too great for the methods of analysis at our command, and the problems remain unsolved.

Very different results are revealed when we turn to the second principal branch of the modern theory, the theory of the *average or asymptotic distribution of primes.* This theory (though one of its most famous problems is still unsolved) is in some ways almost complete, and certainly represents one of the most remarkable triumphs of modern analysis. The theory centres round one theorem, the *Primzahlsatz* or *Prime Number Theorem*; and it is to the history of this theorem, which may almost be said to embody the history of the whole subject, that I shall devote the remainder of this lecture.*

The problem may be stated crudely as follows: *How many primes*

* A full account of the history of the theorem will be found in Landau's *Handbuch der Lehre von der Verteilung der Primzahlen* (Teubner, 1909).

are there less than a given number x? More precisely, let $\pi(x)$ denote the number of primes * not exceeding x: then *what is the order of magnitude of $\pi(x)$?* The Prime Number Theorem provides a complete answer to this last question. It asserts that

$$\pi(x) \sim \frac{x}{\log x},$$

that is to say, that $\pi(x)$ *and* $x/(\log x)$ *are asymptotically equivalent,* or that their ratio tends to 1 when x tends to infinity.

The first step towards the proof of this theorem was made by Euclid, when he proved that the number of primes is infinite, or that

$$\pi(x) \to \infty.$$

Euclid's proof is classical, and can hardly be repeated too often. If the number of primes is finite, let them be 2, 3, 5, . . ., P. The number 2. 3. 5. . . . P + 1 is not divisible by any of 2, 3, 5, ..., P. It is therefore prime itself, or divisible by some prime greater than P; and either alternative contradicts the hypothesis that P is the greatest prime. It is worth remarking that Euclid's reasoning may be used to prove rather more, viz. that the order of $\pi(x)$ is at least as great as that of $\log \log x$.†

The next advances were made by Euler, probably about 1740. It was Euler to whom we owe the introduction into analysis of the Zeta-function, the function on whose properties, as later research has shown, the whole theory depends.

Let $s = \sigma + it$. Then the function $\zeta(s)$ is defined, when $\sigma > 1$, by the equations

$$\zeta(s) = \Sigma n^{-s} = 1^{-s} + 2^{-s} + 3^{-s} + \ldots;$$

and Euler's fundamental contribution to the theory is the formula

$$\zeta(s) = \Pi\left(\frac{1}{1-p^{-s}}\right),$$

where the product extends over all prime values of p. Euler, it is true, considered $\zeta(s)$ as a function of a *real* variable only. But his formula at once indicates the existence of a deep-lying connection between the theory of $\zeta(s)$ and the theory of primes.

Euler deduced from his formula that the series Σp^{-s}, obviously convergent when $s > 1$, is divergent when $s = 1$; and from this it is easy to deduce important consequences as to the order of $\pi(x)$. It is evident that $\pi(x) < x$, so that the order of $\pi(x)$ certainly does not exceed that of x, or, in the notation which is usual now, $\pi(x) = O(x)$.‡ It is an easy corollary of Euler's result that the order of $\pi(x)$ is *not very much less than that of* x; that, for example, $\pi(x) \neq O(x^a)$ for any value of a less than 1; or again, more precisely, that

$$\pi(x) \neq O\left\{\frac{x}{(\log x)^{1+a}}\right\}$$

for any value of a greater than 1.

* It proves most convenient not to count 1 as a prime.

† This was pointed out to me by Prof. H. Bohr of Copenhagen.

‡ $f = O(\phi)$ means that the absolute value of f is less than a constant multiple of ϕ thus $\sin x = O(1)$, $100x = O(x)$.

It is also easy to prove that the order of $\pi(x)$ is *definitely less than that of* x, or that, as we should express it now, $\pi(x) = o(x)$.* This theorem, when read in conjunction with those which precede, is, I think, enough to suggest the Prime Number Theorem as a very plausible conjecture, or at any rate to suggest that the true order is that of $x/(\log x)$. The theorem was in fact conjectured first by Gauss (1793) and by Legendre (1798); and it is in Legendre's *Essai sur la théorie des nombres* that the conjecture first appears in print.

In this state the problem remained for fifty years, until the publication (1849–1852) of the researches of the Russian mathematician Tschebyschef. I have no time to speak of Tschebyschef's work as fully as it deserves, but his chief results, in so far as they bear directly on the problem now before us, were as follows:—

(1) Tschebyschef showed that the problem is simplified if we take as fundamental not the function $\pi(x)$ itself, but the closely related function

$$\theta(x) = \sum_{p < x} \log p$$

(the sum of the logarithms of all primes not exceeding x). He showed that the order of $\theta(x)$ is the same as that of $\pi(x) \log x$, and that the Prime Number Theorem itself is equivalent to the theorem that

$$\theta(x) \sim x.$$

(2) He showed that $\theta(x)$ is actually of order x, and $\pi(x)$ of order $x/(\log x)$, in fact that positive constants A and B exist such that

$$A \frac{x}{\log x} < \pi(x) < B \frac{x}{\log x}.$$

(3) He showed that *if* $\theta(x)/x$ *tends to a limit*, then that limit must be unity.

What Tschebyschef could not prove is that the limit does in fact exist, and, as he failed to prove this, he failed to prove the Prime Number Theorem. And about Tschebyschef's methods (interesting as they are), I shall say nothing; for later research has shown that it was the essential inadequacy of his methods which was responsible for his failure, and that the theorem lies deeper in analysis than any of the ideas on which he relied.

The next great step was taken by Riemann in 1859, and it is in Riemann's famous memoir *Ueber die Anzahl der Primzahlen unter einer gegebenen Grösse* that we first find the ideas upon which the theory has now been shown really to rest. Riemann did not prove the Prime Number Theorem: it is remarkable, indeed, that he never mentions it. His object was a different one, that of finding an explicit expression for $\pi(x)$, or rather for another closely associated function, as a sum of an infinite series. But it was Riemann who first recognised that, if we are to solve any of these problems, we must study the Zeta-function as a function of the *complex* variable $s = \sigma + it$, and in particular study the distribution of its zeros.

* $f = o(\phi)$ means that $f/\phi \to 0$. Thus $\sin x = o(x)$. This theorem also was stated by Euler, but without satisfactory proof.

Riemann proved

(1) that $\zeta(s)$ is an analytic function of s, regular all over the plane except for a simple pole at the point 1;

(2) that $\zeta(s)$ satisfies the functional equation

$$\zeta(1-s) = 2(2\pi)^{-s}\cos\tfrac{1}{2}s\pi\ \Gamma(s)\zeta(s);$$

(3) that $\zeta(s)$ has zeros at the points $-2, -4, -6 \ldots$, and no other zeros *except possibly complex zeros whose real parts lie between* 0 *and* 1 *inclusive.*

To these propositions he added certain others of which he could produce no satisfactory proof. In particular he asserted that there is in fact an infinity of complex zeros, all naturally situated in the 'critical strip' $0 \leq \sigma \leq 1$; an assertion now known to be correct. Finally he asserted that it was 'sehr wahrscheinlich' that all these zeros have the real part $\frac{1}{2}$: the notorious 'Riemann hypothesis', unsettled to this day.

We come now to the time when, a hundred years after the conjectures of Gauss and Legendre, the theorem was finally proved. The way was opened by the work of Hadamard on integral transcendental functions. In 1893 Hadamard proved that the complex zeros of Riemann actually exist; and in 1896 he and de la Vallée-Poussin proved independently that *none of them have the real part* 1, and deduced a proof of the Prime Number Theorem.

It is not possible for me now to give an adequate account of the intricate and difficult reasoning by which these theorems are established. But the general ideas which underlie the proofs are, I think, such as should be intelligible to any mathematician.

In the first place Euler's formula shows that $\log\zeta(s)$ behaves, throughout the half-plane $\sigma > 1$, much like the series Σp^{-s}. But $\zeta(s)$ has a simple pole for $s = 1$, and so the sum of the series $\Sigma p^{-1-\delta}$ tends logarithmically to $+\infty$ when $\delta \to 0$ through positive values. Suppose now that (if possible) $\zeta(1+ti) = 0$. Then the real part of $\log\zeta(1+\delta+ti)$, and therefore the real part of the series $\Sigma p^{-1-\delta-ti}$, tends, also logarithmically, to $-\infty$ when $\delta \to 0$. It follows that the series

$$\Sigma\, p^{-1-\delta},\quad -\Sigma\, p^{-1-\delta}\cos(t\log p)$$

tend to $+\infty$ *with equal rapidity* when $\delta \to 0$. As the first series is a series of positive terms, while the signs of the terms in the second series change with a certain regularity, it is natural to suppose that our last conclusion is impossible; and this is in fact not particularly difficult to prove.

I come now to the proof of the Prime Number Theorem itself. If we differentiate Euler's formula logarithmically, we obtain

$$\frac{\zeta'(s)}{\zeta(s)} = \Sigma\left(\frac{\log p}{p^s} + \frac{\log p}{p^{2s}} + \ldots\right) = \sum_{p,m}\frac{\log p}{p^{ms}};$$

or

$$-\frac{\zeta'(s)}{\zeta(s)} = \Sigma\frac{\Lambda(n)}{n^s} \qquad (1)$$

where p assumes all prime values, m and n all positive integral values,

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and $\Lambda(n)$ is equal to $\log p$ if n is of the form p^m and to zero otherwise. Let

$$\psi(x) = \sum_{n \leq x} \Lambda(n)$$

Then $\psi(x)$ is, for our present purpose, equivalent to $\theta(x)$: it is easy to show that the difference between the two functions is of order $\sqrt{x}$. We have therefore to prove that $\psi(x) \backsim x$.

The series on the right-hand side of the equation (1) is what is called a 'Dirichlet's series'; and the theory of such series resembles the more familiar theory of Taylor's series in one very important respect. *We can express the coefficients by contour integrals in which the function represented by the series appears under the sign of integration.* In particular we can show that

$$\psi(x) = -\frac{1}{2\pi i}\int \frac{\zeta'(s)}{\zeta(s)} \frac{x^s}{s}\, ds, \tag{2}$$

where the path of integration is a line parallel to the imaginary axis and passing to the right of the point $s=1$.

The general idea of the proof is now easy enough to grasp. Every element of the integral (2) is of order x^σ, where $\sigma > 1$: we can therefore draw no *direct* conclusion as to the behaviour of $\psi(x)$ when x is large. But it is at once suggested that we should try to make use of Cauchy's theorem. The subject of integration has a simple pole at the point 1, corresponding to the pole of $\zeta(s)$ itself, and the residue at the pole is precisely x; and there are no other singularities on the line $\sigma = 1$, since $\zeta(s)$, as we have seen, has no poles *or zeros* on that line. Suppose then that we can move the path of integration across to the left of the line, introducing the appropriate correction due to the pole. Plainly we shall then have an expression for $\psi(x) - x$ in the form of an integral *in which every element is of order less than that of* x. And if we can show that the same is true of the integral itself, we shall have proved that $\psi(x) \backsim x$, that is to say, we shall have proved the Prime Number Theorem. It will be observed that, if $\zeta(s)$ had zeros whose real part is equal to 1, then the result would be definitely false, since there would be additional residues of order x. It thus becomes clear why the older attempts to prove the theorem, without using the theory of functions of a complex variable, were unsuccessful.

The arguments which I have advanced are not exact: I have merely put forward a chain of reasoning which seems likely to lead to the desired result. The achievement of Hadamard and de la Vallée-Poussin was to replace these plausibilities by rigorous proofs. It might be difficult for me to make clear to you how great this achievement was. Some branches of pure mathematics have the pleasant characteristic that what seems plausible at first sight is generally true. In this theory one can make plausible conjectures, and they are almost always false. Nothing short of absolute rigour counts; and it is for this reason that the Analytic Theory of Numbers, while hardly a subject for an amateur, provides the finest possible discipline in accurate reasoning for those who will make a real effort to understand its results.

TRANSACTIONS OF THE SECTIONS.

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SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

PRESIDENT OF THE SECTION:—SIR F. W. DYSON, M.A., LL.D., F.R.S

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address:—

ALTHOUGH at the present time our minds are largely absorbed by the war the meeting of the British Association in Manchester indicates that we consider it right to make our annual review of scientific progress. I shall therefore make no apology for choosing the same subject for my address as I should have chosen in other circumstances. It is a subject far removed from war, being an account of the manner in which astronomers have with telescopes and spectroscopes investigated the skies and the conclusions they have reached on what Herschel called 'The Construction of the Heavens.'

Our knowledge of the fixed stars, as they were called by the old astronomers, is of comparatively recent origin, and is derived from two sources: (1) the measurement of small changes in the positions of the stars in the sky, and (2) the analysis of the light received from them and the measurement of its amount. The facts found for separate stars when arranged and classified give us some insight into the structure of the Stellar Universe as a whole. The discovery made by Galileo's telescope that the Milky Way consists of myriads of stars may be taken as the beginning of Sidereal Astronomy. The further study of the number of the stars and their general distribution has grown with the light-grasping powers of the telescope, and in recent times has had the assistance of photography.

The changes of position of the stars among themselves are of two kinds. The first consist of small periodic movements about a mean position due to parallax, and in the case of double stars due to orbital motion. The observation of these small angles has been made possible by the development of the telescope for refined measurement. The most important contributions to this are the Equatorial movement, the position micrometer, the heliometer, and the application of photography. For the purpose of measurement the increase in focal length and the perfect optical definition of the telescope are of greater importance than increase in light-grasping power.

The second class of movements, the proper motions of stars, are determined by the comparison of the positions of the stars after an interval of years. The accurate positions of stars in the sky are found by means of the transit-circle and the astronomical clock. Both of these instruments have been slowly brought to a high degree of perfection. The use of photography makes it possible to extend the study of proper motions to the fainter stars.

Accurate measures of the light of the stars have been in progress for the last fifty years by the applications of photometers of various kinds to the telescope. Many observations of magnitude, especially of variable stars, have also been made by estimation, but are brought to a uniform scale by comparison with photometric measures. In the last few years photography has been very successfully applied to determine stellar magnitudes, and seems likely to supersede visual observations to a large extent.

By spectroscopic analysis the stars may be classified according to their physical characteristics, and their velocities in the line of sight may be determined. For the purposes of classification, objective prisms have been generally employed, and the spectra of many stars obtained on one photographic plate. The measurement of velocities in the line of sight is a more delicate operation, and although initiated in the 'sixties, it was not till the application of photography thirty years later that results of value were obtained. This class of observation requires a large telescope and a spectroscope very carefully designed and constructed.

This very brief summary of the different kinds of observations made in the study of the stars may remind you to what extent progress has been dependent on the development of astronomical instruments. The desire to examine fainter objects, and still more the necessity of increasing the accuracy of observations, has brought about a continuous improvement in the range and accuracy of astronomical instruments. Methods which had been perfected for observations of a few stars have been extended so that they can be applied to a large number. For these reasons the progress of Sidereal Astronomy may seem to have gone on slowly for a time. The more rapid progress of recent years arises from the accumulation of data, for which we are indebted to generations of astronomers, and from the gradual increase in power and perfection of our instruments.

The first insight into the stars as a whole naturally came from the survey of their numbers and distribution; and Herschel, who constructed the first great telescopes, explored the heavens with untiring skill and energy, and speculated boldly on his observations, is justly regarded as the founder of Sidereal Astronomy. In his great paper, 'On the Construction of the Heavens,' Herschel gives the rules by which he was guided, which I should like to quote, as they may well serve as a motto to all who are engaged in the observational sciences :

'But first let me mention that if we would hope to make any progress in an investigation of this delicate nature we ought to avoid two opposite extremes of which I can hardly say which is the most dangerous. If we indulge a fanciful imagination and build worlds of our own, we must not wonder at our going wide from the path of truth and nature; but these will vanish like the Cartesian vortices, that soon gave way when better theories were offered. On the other hand, if we add observation to observation, without attempting to draw not only certain conclusions but also conjectural views from them, we offend against the very end for which only observations ought to be made. I will endeavour to keep a proper medium; but if I should deviate from that I could wish not to fall into the latter error.' In this spirit he discussed the 'star gauges' or counts of stars visible with his great reflector in different parts of the sky, and concluded from them that the stars form a cluster which stretches to an unknown but finite distance, considerably greater in the plane of the Milky Way than in the perpendicular direction. He gave this distance as 497 times that of Sirius. He did not hesitate to advance the theory that some of the nebulæ were similar clusters of stars, of which that in Andromeda, judging from its size, was the nearest. Herschel had no means of telling the scale of the sidereal system, though he probably supposed the parallax of Sirius to be of the order of 1″.

Though some of the assumptions made by Herschel are open to criticism, the result at which he arrived is correct in its general outline. I shall attempt to give a brief account of some of the principal methods used to obtain more definite knowledge of the extent and constitution of this 'island universe.' The stars of which most is known are, in general, those nearest to us. If the distance of a star has been measured, its co-ordinates, velocity perpendicular to the line of sight and luminosity are easily found. In the case of a double star whose orbit is known the mass may also be determined. But only a very small proportion of the stars are sufficiently near for the distance to be determinable with any accuracy. Taking the distance corresponding to a parallax of 1″ or the parsec as unit—*i.e.*, 200,000 times the distance of the Earth from the Sun—fairly accurate determinations can be made up to a distance of 25 parsecs, but only rough ones for greater distances.

For much greater distances average results are obtainable from proper motions, and the mean distances of particular classes of stars—for instance, stars of a given magnitude or given type of spectrum—can be found with confidence up to a distance of 500 parsecs, and with considerable uncertainty to twice this distance. The density of stars in space as a function of the distance, the percentage of stars within different limits of luminosity, the general trend of the movements of stars and their average velocities can also be found, within the same limits of distance.

For all distances, provided the star is sufficiently bright, its velocity to or from the earth can be measured. The general consideration of these velocities supplies complementary data which cannot be obtained from proper motions, and confirms other results obtained by their means.

For distances greater than 1,000 parsecs our knowledge is generally very vague. We have to rely on what can be learned from the amount and colour of the light of the stars, and from their numbers in different parts of the sky.

Parallax.

Let us begin with the portion of space nearest to us, within which the parallaxes of stars are determinable. The successful determination of stellar parallax by Bessel, Struve, and Henderson in 1838 was a landmark in Sidereal Astronomy. The distances of three separate stars were successfully measured, and for the first time the sounding line which astronomers had for centuries been throwing into space touched bottom.

The employment of the heliometer which Bessel introduced was the main source of our knowledge of the distances of stars till the end of the nineteenth century, and resulted in fairly satisfactory determination of the parallaxes of less than 100 stars.

Nineteen stars have been found to be within a sphere of radius 5 parsecs, or a million times the Sun's distance. We cannot say that all the stars within this distance have been discovered, but there are good reasons to think that most of them have been found. Leaving out stars of very faint luminosity—less than $\frac{1}{2500}$th part of the luminosity of the Sun—Professor Eddington estimates the total number in this volume as thirty-two. This gives that in the space near the Sun the average distance of the stars from one another is $2\frac{1}{2}$ to 3 parsecs—or twice the distance of the Sun from its nearest neighbour α Centauri.

A considerable proportion of these stars are double and the orbits of several have been determined. The distance being known, the linear dimensions of the orbit are immediately determined and the masses. From these somewhat scanty data it is found that there is not a great range in the masses of stars. Thus the combined mass of Sirius and its companion is three and a half times that of the Sun, and the total mass of α Centauri is twice that of the Sun. These results are confirmed statistically by observations of spectroscopic binary stars and of other double stars. There is no evidence of any stars with masses a hundred times greater than the Sun or of any with much smaller masses. According to Prof. Russell, the largest stellar mass of which we know is the spectroscopic binary and eclipsing variable star V Puppis, and this is 19 times as massive as the Sun. Further, it seems, as has been pointed out by Ludendorf and Halm, that the bright helium stars are the most massive, being on the average seven times as massive as the Sun.

When the absolute luminosities of the stars whose distances have been measured are calculated, it is found that, unlike the masses, they exhibit a very great range. For example, Sirius radiates forty-eight times as much light as the Sun and Groombridge 34 only one hundredth part. This does not represent anything like the complete range, and Canopus, for example, may be ten thousand times as luminous as the Sun. But among the stars near the Solar system, the absolute luminosity appears to vary with the type of spectrum. Thus Sirius, of type A, a blue hydrogen star, is forty-eight times as luminous as the Sun; Procyon of type F5—bluer than the Sun but not so blue as Sirius—ten times; α Centauri, which is nearly of Solar type, is twice as luminous 61 Cygni of type K5—redder than the Sun—one-tenth as luminous; while the still redder star of type Ma, Gr 34, is only one-hundredth

as luminous. In the neighbourhood of the Solar system one-third of the stars are more luminous and two-thirds less luminous than the Sun. The luminosity decreases as the type of spectrum changes from A to M, *i.e.*, from the blue stars to the red stars.

These three results as to the density in space, the mass and the luminosity have been derived from a very small number of stars. They show the great value of accurate determinations of stellar parallax. As soon as the parallax is known, all the other observational data are immediately utilisable. At the commencement of the present century the parallaxes of perhaps 80 stars were known with tolerable accuracy. Happily the number is now rapidly increasing by the use of photographic methods. Within the last year or two, the parallaxes of nearly two hundred stars have been determined and published. This year a Committee of the American Astronomical Society, under the presidency of Prof. Schlesinger, has been formed to co-ordinate the work of six or seven American and one or two English observatories. The combined programme contains 1,100 stars, of which 400 are being measured by more than one observatory. We may expect results at the rate of two hundred a year, and may therefore hope for a rapid increase of our knowledge of the stars within our immediate neighbourhood.

Velocities in the Line of Sight.

The determination of radial velocities was initiated by Huggins in the early 'sixties, but reliable results were not obtained till photographic methods were introduced by Vogel in 1890. Since that time further increase in accuracy has been made, and the velocity of a bright star with sharp lines is determinable (apart from a systematic error not wholly explained) with an accuracy of ½ kilomètre per second. As the average velocities of these stars are between 10 and 20 kilomètres a second, the proportional accuracy is of a higher order than can be generally obtained in parallax determinations or in other data of Sidereal Astronomy. A number of observatories in the United States and Europe, as well as in South America, the Cape, and Canada are engaged in this work. Especially at the Lick Observatory under Prof. Campbell's direction, the combination of a large telescope, a well-designed spectroscope, and excellent climatic conditions have been utilised to carry out a bold programme. At that observatory, with an offshoot at Cerro San Christobal in Chile, for the observation of stars in the Southern Hemisphere, the velocities of 1,200 of the brightest stars in the sky have been determined. Among the results achieved is a determination of the direction and amount of the Solar motion. The direction serves to confirm the results from proper motions, but the velocity is only obtainable accurately by this method. This quantity which enters as a fundamental constant in nearly all researches dealing with proper motion, is given by Campbell at 19·5 kilomètres per second, or 4·1 times the distance of the Earth from the Sun per annum, though there is some uncertainty arising from a systematic error of unknown origin.

Variation of their radial velocity shows that a large proportion of stars are spectroscopic binaries, and the results have been discussed by Campbell from the point of view of the genesis of the double stars by fission. It would be somewhat outside the scope of my address to speak further of this. I have already drawn attention to the fact that we derive from spectroscopic binary stars a considerable part of our somewhat scanty knowledge of the masses of stars.

The observations of radial velocities have shown within what limits the velocities of stars lie and have given a general idea of their distribution. The most important result, and one of a somewhat surprising character, is that the mean velocities of stars, the motion of the Sun being abstracted, increase with the type of spectrum. Thus the stars of type B, the helium stars, the stars of the highest temperature, have average radial velocities of only 6·5 kilomètres per second; the hydrogen stars of type A have average velocities of 11 kilomètres per second; the Solar stars of 15 kilomètres per second; while for red stars of types K and M it has increased slightly more to 17 kilomètres per second. Further, the few planetary nebulæ—*i.e.*, condensed nebulæ with bright line spectra—have average velocities of 25 kilométres per second. There

can be no question of the substantial accuracy of these results, as they are closely confirmed by discussions of proper motions. They are, however, very difficult to understand. On the face of it, there does not seem any reason why stars of a high temperature should have specially high velocities. A suggestion has been thrown out by Dr. Halm that as the helium stars have greater masses, these results are in accordance with an equi-partition of Energy. But the distance of stars apart is so great that it seems impossible that this could be brought about by their interaction. Prof. Eddington suggests that the velocities may be an indication of the part of space at which the stars were formed (*e.g.*, stars of small mass in outlying portions), and represents the kinetic energy they have acquired in arriving at their present positions.

The stars whose radial velocities have been determined are, generally speaking, brighter than the fifth magnitude. Fainter stars are now being observed. At the Mount Wilson Observatory, Prof. Adams has determined the velocities of stars of known parallaxes, as there are great advantages in obtaining complete data for stars where possible. Extension of line-of-sight determinations to fainter stars is sure to bring a harvest of useful results, and a number of great telescopes are engaged, and others will shortly join in this important work.

Proper Motions.

As proper motions are determined by the comparison of the positions of stars at two different epochs, they get to be known with constantly increasing accuracy as the time interval increases. The stars visible to the naked eye in the Northern Hemisphere were accurately observed by Bradley in 1755 Many thousands of observations of faint stars down to about $9^{m}\cdot0$ were made in the first half of the nineteenth century. An extensive scheme of re-observation was carried out about 1875 under the auspices of the Astronomische Gesellschaft. A great deal of reobservation of stars brighter than the ninth magnitude has been made this century in connection with the photographic survey of the heavens For the bright stars all available material has been utilised, and their proper motions have been well determined, and for the fainter stars this is being gradually accomplished.

Proper motions differ widely and irregularly in amount and direction. Herschel observed a tendency of a few stars to move towards one point of the sky, and attributed this sign of regularity to a movement of the Solar system in the opposite direction. As the amount of material increased, the question was examined in different ways by Bessel, Argelander, and Airy Bessel's method did not indicate the Solar motion, while Airy's showed it plainly. The cause of this discrepancy was not explained for more than half a century. The publication by Auwers of very accurate proper motions of the stars observed by Bradley, consisting roughly of 3,200 stars visible to the naked eye in these latitudes, caused a number of astronomers to make fresh determinations of the direction of the Solar motion. But the puzzling differences given by different methods remained unexplained till the difficulty was resolved by Prof. Kapteyn in a paper read before this Section of the British Association at its meeting in South Africa ten years ago. He showed that the proper motions had a general tendency towards two different points of the sky and not towards one only, as would be expected if the motions of the stars themselves were haphazard, but viewed from a point in rapid motion. He concluded from this that there was a general tendency of the stars to stream in two opposite directions. It is interesting to notice that this great discovery was made by a simple graphical examination of the proper motions of stars in different regions of the sky, after the author had spent much time in examining and criticising the different methods which had been adopted for the determination of the direction of the Solar motion.

The subject was brought into a clearer and more exact shape by the analytical formulation given to it by Prof. Eddington. He employed the proper motions of some 4,000 stars determined from the comparison of Groombridge's observations in 1810 with modern observations at Greenwich. These stars are more suitable than Bradley's for analytical treatment, as there are a larger number of them per unit area of the sky. This analytical treatment

was modified by Prof. Schwarzschild, who considered the stars, not as two separate streams, but as exhibiting a polarity in their proper motions. It is difficult to say which of the two harmonises better with the observations—they agree in the most essential fact, that the stars have a very decided preference for motion towards a point in the Milky Way situated in the constellation of Ophiuchus and the opposite point in the constellation of Orion.

This star-streaming is corroborated by observations of velocities in the line of sight. It applies—with the exception of the helium stars—to all stars which are near enough for their proper motions to be determinable. We may say with certainty that it extends to stars at distances of two or three hundred parsecs; it may extend much further, but I do not think we have at present much evidence of this. Prof. Turner pointed out that the convergence of proper motions did not necessarily imply movements in parallel directions, and suggested that the star-streams were movements of stars to and from a centre. The agreement of the radial velocities with the proper motions seems to me to be opposed to this suggestion, and to show that star-streaming indicates approximate parallelism in two opposite directions in the motions of the stars examined. As the great majority of these stars are comparatively near to us, it is possible that this parallelism is mainly confined to them, and indicates the general directions of the orbital motions of stars in the neighbourhood An attempted explanation on these lines, as on Prof. Turner's, implies that the Sun is some distance from the centre of the stellar system.

A discovery of an entirely different character was made by Prof. Boss in 1908. He spent many years in constructing a great catalogue giving the most accurate positions and motions of 6,200 stars obtainable from all existing observations. This catalogue, which was published by the Carnegie Institute, was intended as a preliminary to a still larger one which would give the accurate positions and motions of all the stars down to the seventh magnitude. In the introduction to the catalogue, Boss remarks that this collation of the results of meridian observations in a large and comprehensive way is only the second attempt which has yet been made by astronomers. The first, it is interesting to notice, was a general catalogue of 8,377 stars compiled by Francis Baily and published by the British Association in 1845. At that time the proper motions could only be given for a very limited number of stars, but in Boss's catalogue proper motions are given for all the stars, and their probable errors are not more than $0''.5$ per century In the course of this work Professor Boss found that forty or fifty stars scattered over a considerable region of the sky near the constellation Taurus were all moving towards the same point in the sky and with nearly the same angular velocity. He inferred that these stars were all moving in parallel directions with an equal linear velocity, and the supposition was verified, in the case of several of them, by the determination of their radial velocities. From these data he was able to derive the distance of each star and thus its position in space. The existence of a large group of stars, separated from one another by great distances, and all having the same motion in space, is a very remarkable phenomenon. It shows, as was pointed out by Prof Eddington, how small is the gravitational action of one star on another, and that the movement of each star is determined by the total attraction of the whole mass of the stars. Several other interesting moving clusters have been found since. For all the stars belonging to these clusters, the distances have been found, and from them luminosities and velocities of individual stars, particulars which are generally only obtainable for stars much nearer to us.

Proper motions are the main source of our knowledge of the distances of stars which are beyond the reach of determination by annual parallax. If a star were known to be at rest its distance could be calculated from the shift of its apparent position caused by the translation of the Solar motion. As the Solar system moves 410 times the distance of the Earth from the Sun in a century, this gives a displacement of $1''$ for a star at the distance of 500 parsecs. This method has been applied by Kapteyn to determine the distances of the helium stars, as their velocities are sufficiently small to be neglected in comparison with that of the Solar system. But generally it is only possible to find the mean distances of groups of stars of such size that it

may be assumed that the peculiar motions neutralise one another in the mean. For example, the average distance of stars of type A, or stars of the fifth magnitude, or any other group desired may be found. In this way Kapteyn has found from the Bradley stars that the mean parallax of stars of magnitude m is given by the formula $\log \pi_m = -1{\cdot}108 - 0{\cdot}125\, m$.

In conjunction with another observational law which expresses the number of stars as a function of the magnitude, this leads to a determination of the density of stars in space at different distances from us, and also of the 'luminosity law,' *i.e.*, the percentage of stars of different absolute brightness. Professors Seeliger and Kapteyn have shown in this way that there is a considerable falling off of star-density as we go further from the Solar system. It seems to me very necessary that this should be investigated in greater detail for different parts of the sky separately. A general mathematical solution of general questions which arise in the treatment of astronomical statistics has been given by Professor Schwarzschild. His investigations are of the greatest value in showing the exact dependence of the density, luminosity, and velocity laws on the statistical facts which can be collected from observation. The many interesting statistical studies which have been made are liable to be rather bewildering without the guidance furnished by a general mathematical survey of the whole position.

When the proper motions are considered in relation to the spectral types of the stars, the small average velocities of the hydrogen stars and still smaller ones of the helium stars found from line-of-sight observations are confirmed. If stars up to a definite limit of apparent magnitude, say, to 6·0 m., or between certain limits, say, 8·0 m. and 9·0 m., are considered, then the Solar stars are found to be much nearer than either the red or the blue stars. Thus both red and blue stars must be of greater intrinsic luminosity than the Solar stars. As regards blue stars, this agrees with results given by parallax observations. But the red stars appear to consist of two classes, one of great and one of feeble luminosity, and it does not seem that a sufficient explanation is given by the fact that a selection of stars brighter than any given apparent magnitude will include the very luminous stars which are at a great distance, but only such stars of feeble luminosity as are very near.

The significance of these facts was pointed out by Prof. Hertzsprung and Prof. Russell. They have a very important bearing on the question of stellar evolution, a subject for discussion at a later meeting this week. From the geometrical standpoint of my address these facts are of importance in that they help to classify the extraordinarily large range found in the luminosities of stars. Putting the matter somewhat broadly, the A stars, or hydrogen stars, are on the average intrinsically 5 magnitudes brighter than the Sun, whilst the range in their magnitudes is such that half of them are within $\frac{3}{4}$ magnitude of the mean value. The stars of type M, very red stars, are of two classes. Some of them are as luminous as the A stars, and have a similar range about a mean value 5 magnitudes brighter than the Sun. Others, on the contrary, have a mean intrinsic brightness 5 magnitudes fainter than the Sun and with the same probable deviation of $\frac{3}{4}$ magnitude. Between the types M and A there are two classes whose distance apart diminishes as the stars become bluer. The facts in support of this contention are very forcibly presented by Prof. Russell in *Nature* in May 1914. If this hypothesis is true, and it seems to me there is much to be said in its favour, then the apparent magnitude combined with the type of spectrum will give a very fair approximation to the distances of stars which are too far away for their proper motions to be determinable with accuracy.

In dealing with the proper motions of the brighter stars, the sky has been considered as a whole. Now that the direction and amount of the solar motion are known, we may hope that, as more proper motions become available, the different parts of the sky will be studied separately. In this way we shall obtain more detailed knowledge of the streaming, and also of the mean distances of stars of different magnitudes in all parts of the sky, leading to a determination of how the density of stars in space changes in different directions. A second line of research which may be expected to give important results is in the relationship of proper motions to spectral type. There is in

preparation at Harvard College, by Miss Cannon under Prof. Pickering's direction, a catalogue giving the type of spectrum of every star brighter than the ninth magnitude. It would be very desirable to determine the proper motions of all these stars. If all the material available is examined it should be possible to do this to a very large extent.

Photometry and Colour.

For the more distant parts of the heavens proper motions are an uncertain guide, and we must depend on what can be learned from the light of the stars by means of stellar photometry, determinations of colour, and studies of stellar spectra Speaking generally, we attempt to discover from the nearer stars sufficient about their intrinsic luminosities to enable us to use the apparent magnitude as an index of the distances of the stars which are further away. The most striking example is found in Prof. Hertzsprung's determination of the distance of the small Magellanic Cloud. Visitors to Australia last year may have seen in the sky two faint patches of light which look like pieces torn off the Milky Way. These are called the Magellanic Clouds. In the small cloud Miss Leavitt found 25 variable stars of special character known as Cepheids. They are all very faint stars between 11·2 m. and 16·4 m. on the photographic scale. The periods of their light variation range from 1·25 days to 127 days. Miss Leavitt found that a linear relationship existed between the logarithm of the period and the apparent magnitude. As these stars all belong to the Magellanic Cloud they are at the same distance, and thus there is a relationship between the period of light variation and the intrinsic magnitude. Prof. Hertzsprung found in Boss's catalogue 13 variable stars of similar class of known proper motion. He deduced their mean distance by using the solar motion, and from this calculated the mean intrinsic luminosity. He thus found that Cepheid variables with a period of 6·6 days are 600 times as luminous as the Sun, and have an absolute magnitude of −7·3 m. But from Miss Leavitt's observations similar stars in the small Magellanic Cloud have an apparent visual magnitude of 13·0 m. Thus the small Magellanic Cloud is at such a distance that a star in it is 20·3 m. fainter than it would be if at a distance of one parsec, from which it follows that the distance of this cloud is 10,000 parsecs.

This example illustrates the utility of exact measurements of the light of the stars. Much attention has been given of late years to Stellar Photometry. In 1899 Prof. Pickering published the Revised Harvard Photometry giving the magnitudes of all stars brighter than 6·5 m. In 1907 Messrs. Muller and Kempf completed a determination of 14,199 stars of the Northern Hemisphere brighter than 7·5 m. In 1908 a catalogue of 36,682 stars fainter than 6·5 m. was published at Harvard. These determinations derive additional importance as they give the means of standardising estimates of magnitude made by eye, particularly the many thousands of the Bonn Durchmusterung.

By the labours of Prof. Pickering and his colleagues at Harvard, Prof. Schwarzschild, Prof. Parkhurst at Yerkes, Prof. Seares at Mount Wilson, and others, the determinations of the magnitudes of stars by photography has made rapid strides. As yet no complete catalogues of photographic magnitudes corresponding to the Revised Harvard Photometry have been published, though considerable parts of the sky and special areas such as the Pleiades have been carefully studied. The determination of the photographic magnitudes of any stars which may be required is, however, a comparatively simple matter when the magnitudes of sufficient standard stars have been found. A trustworthy and uniform scale has been to a large extent secured by the use of extrafocal images, gratings, and screens in front of the object glass, and the study of the effects of different apertures and different times of exposure.

At Harvard and Mount Wilson, standard magnitudes of stars near the North Pole have been published extending to nearly the twentieth magnitude. In the part of the range extending from 10·0 m. to 16·0 m. these agree very satisfactorily. Near the limit at magnitude 20·0 m. there is naturally some discordance, as might be expected, but for the present this is not of great importance. There is, however, a difference of 0·4 m. in the scale between 6·0m. and 10·0m. which needs to be cleared up. I may remind you, to make

it quite clear what this scale means, that for every increase of 5·0 m. there is a diminution of light in the proportion of 100 :1. Thus the total range in going from the brightest stars to those of 20·0 m. is more than 10^8 to 1.

A uniform and accurate scale of magnitude is of fundamental importance in counts of the numbers of stars. Such counts aim at the determination of two things : (1) how the numbers vary in different parts of the sky, and (2) what is the ratio of the number of stars of each magnitude to that of the preceding magnitude in the same area of the sky. The counts of stars from the gauges of Sir William and Sir John Herschel, those of the stars contained in the Bonn Durchmusterung, those made by Prof. Celoria, and the recent counts of the Franklin-Adams plates, all agree in showing a continuous increase of stars as we proceed from the pole of the Galaxy to the Galaxy itself. The importance of this fact is that it shows a close connection between the Milky Way and the stars nearer to us. The Milky Way is not a system of stars beyond the others, but is the primary feature of our 'island universe.'

So far there is general agreement. Depending mainly on the counts of Sir John Herschel made at the Cape, and the Cape Photographic Durchmusterung, Prof. Kapteyn finds a very great concentration of faint stars towards the Milky Way. On the other hand, the Bonn Durchmusterung, the counts of Prof Celoria, and the recent counts of the Franklin-Adams plates by Mr. Chapman and Mr Melotte give nearly the same concentration, *e.g.*, the proportion of 16 0 m. to 9 0 m. stars does not vary much at different distances from the Galaxy According to these counts, the total number of stars brighter than 6·0 m is approximately four times the number brighter than 5 0 m. in all parts of the sky ; the number brighter than 9 0 m. is three times the number brighter than 8·0 m ; the number greater than 15 0 m. is double that greater than 14·0 m. From the gradual diminution of the ratio for successive magnitudes, the total number for the whole sky is inferred to be between 1,000 and 2,000 millions, the median coming about the magnitude 23·0 m. The total amount of light received from all the stars is equivalent of 700 or 800 stars of the first magnitude, of which half comes from the stars brighter than 10·0 m. These counts do not by themselves make it possible to determine how the stars fall off in density. But as Prof. Eddington has pointed out, they give a measure of the flattening of the stellar system in the ratio of $3\frac{1}{2}$ to 1. If there is a concentration of faint stars in the Milky Way, as maintained by Prof. Kapteyn, this ratio will be increased.

Photometric observations have acquired additional importance from the differences between photographic and visual magnitudes. The ordinary plate is more sensitive to blue light than the eye, and the difference between the photographic and visual (or photo-visual) magnitude of a star is an index of the colour. The colour index is found by observation to be related very closely to the type of spectrum. Prof. Seares has shown from the Colour Indices that as the stars become fainter they become progressively redder. Prof. Hertzsprung has found the same thing by the use of a grating in front of the object glass. Among stars of 17·0 m. visual magnitude, Seares found none with a colour index less than ·7 ; this is approximately the colour index of a star of Solar type, *i.e.*, near the middle of the range from blue stars to red stars.

There are three ways in which this may occur. The stars may be bright but very distant red stars ; or they may be faint red stars, like those in the immediate neighbourhood of the Sun ; or there may have been an absorption of blue light. It is not possible to say in what proportion these causes have contributed. The red stars of 9·0 m. and 10 0 m. are nearly all very luminous but distant bodies, but it seems likely that stars of 17 0 m. will contain a greater proportion of stars of small luminosity.

The absorption of light in space is very small and as yet imperfectly determined. Prof. Kapteyn and Mr. Jones, by comparing the colour indices of stars of large and small proper motion, make the difference between the absorption of photographic and visual light as 1 m. in 2,000 parsecs. The question has been examined directly by Prof. Adams, who has obtained spectra of near and distant stars which are identical as regards their lines, and has examined the distribution of the continuous light. This direct method of comparison showed that the more distant star was always weaker in violet light. But as

both these investigations show that very luminous stars are intrinsically somewhat bluer than less luminous stars of the same spectral type, the two causes require further research for their disentanglement. The question is of importance, as it may serve in some cases to determine the distances of very remote bodies whose type of spectrum is known.

It must be admitted that we are as yet very ignorant of the more distant parts of the 'island universe.' For example, we can make little more than guesses at the distance of the Milky Way, or say what part is nearest to us, what are its movements, and so on. But, nevertheless, the whole subject of the Construction of the Heavens has been opened up in a remarkable manner in the last few years. The methods now employed seem competent to produce a tolerably good model showing the co-ordinates and velocities of the stars as well as their effective temperatures and the amount of light they radiate. Industry in the collection of accurate data is required, along with constant attempts to interpret them as they are collected. The more accurate and detailed our knowledge of the stellar system as it is now, the better will be our position for the dynamical and physical study of its history and evolution.

The following business was then transacted :—

1. *Discussion on Radioactive Elements and the Periodic Law.*
Opened by Professor F. SODDY, *F.R.S.*

2. *Report of the Seismological Committee.*—See Reports, p. 52.

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3. *Dr. John Dalton's Lectures and Lecture Illustrations in Natural Philosophy.* *By* Professor W. W. HALDANE GEE.

THURSDAY, SEPTEMBER 9.

The following business was transacted :—

1 *Discussion on Spectral Classification of Stars and the Order of Stellar Evolution.* *By* Professor A. FOWLER, *F.R.S.*

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2. *Single Line Spectra of the Elements.* *By* Professor J. C. MCLENNAN.

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3. *On Prime Numbers.* *By* G. H. HARDY, *F.R.S.*—See Reports, p. 350.

4. *Time Space and Relativity.* *By* Professor A. N. WHITEHEAD, *F.R.S.*

FRIDAY, SEPTEMBER 10.

The following business was transacted :

1. *Discussion on Thermionic Emission.*
Opened by Professor O. W. RICHARDSON, *F.R.S.*

2. *X-Rays and Crystal Structure.*
By Professor W. H. BRAGG, *F.R.S.*, *and* Mr. W. L. BRAGG.

3. *Optical Dispersion as conditioned by Group Velocity.*
By Professor Sir J. LARMOR, *F.R.S.*

4. *New Views of Magnetism.* *By* Professor PIERRE WEISS.

5. *The Mechanism of Cyclones.* *By* F. J. W. WHIPPLE.

The distribution of pressure and temperature in cyclones in the Temperate Zone has been learned from the analysis of the records from the meteorographs carried by pilot balloons. Up to a height of eight or nine kilomètres the cyclone is composed of air cooler than its surroundings; at greater heights, *i.e.*, in the stratosphere, the cyclone contains comparatively warm air. The lower limit of the stratosphere is depressed in the cyclone. This temperature distribution indicates that the air constituting the lower part of the cyclone has recently ascended, whereas the upper air has recently fallen, and accordingly the arrival of a cyclone is marked by an outflow of air at the bottom of the stratosphere and an inflow below. At the beginning of the present paper the amount of this displacement of air is estimated on the assumption that there is no direct exchange of heat, and it is shown that the outflow is concentrated between the seventh and tenth kilomètres and is about 6.5 times the net loss of air as estimated by the fall of pressure at the earth's surface.

It is pointed out that a cyclone may be regarded as a disturbance in the stream of air which flows from West to East in the Temperate Zone, and the form of the isobars obtained by superimposing the permanent pressure distribution and the temporary cyclonic distribution is discussed. It is shown that when due allowance is made for the curvature and the progressive motion of these isobars, the gradient wind at certain heights is much less than it would have been if the curvature were inappreciable, so that at these heights the air supply from the rear to the front of the cyclone fails and the cyclone appears to move under the influence of suction applied at the base of the stratosphere. The explanation may be summarised as follows :—

If the flow of air at any level were entirely horizontal and along the isobars, and if changes of density were negligible, then the condition for continuity would require the velocity to be inversely proportional to the distance between the isobars, *i.e.*, the velocity would be directly proportional to the pressure gradient. This condition is not satisfied, however, in regions where the air-trajectories are curved. The pressure has to produce the centripetal acceleration in the curved path in addition to overcoming the tendency to turn to the right, which is the feature of all horizontal motion in our hemisphere. Accordingly the actual velocity where the isobars are curved is less than it should be to secure continuity and maintain a stationary distribution of pressure. The effect of curvature in reducing the velocity is greatest at the heights where the winds are strongest, and therefore the suction effect is concentrated near the base of the stratosphere.

The general argument is supported by the analysis of two special cases.

SECTION B.—CHEMISTRY.

PRESIDENT OF THE SECTION:—PROFESSOR W. A. BONE, D.Sc., F.R.S.

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address:—

Gaseous Combustion.

THIS year is, as many of you are doubtless aware, the centenary of Davy's invention of the Miner's Safety Lamp, which formed the starting-point of his brilliant researches upon Flame, in which he disclosed and brought within the range of experimental inquiry most of the intricate and baffling problems connected with the fascinating subject of gaseous combustion. Also, the ground on which we meet to-day is known to the whole scientific world as the place where, during more than a quarter of a century of continuous investigation, a succession of Manchester chemists, led and inspired by Professor H. B. Dixon, have devoted themselves to the elucidation of the many problems which Davy's work foreshadowed. Therefore, both in point of time and place, the occasion is singularly appropriate for a review of recent advances in this important field of scientific inquiry.

At the Sheffield Meeting of this Association in 1910 I had the honour of presenting to a joint conference of Section A and B (Physics and Chemistry) a Report summarising the then 'State of Science in Gaseous Combustion'[1] which gave rise to a keen and stimulating discussion, and was not only printed *in extenso* in the Annual Report for that year, but was also widely circulated through the medium of the scientific and technical press. There is no need, therefore, for me to refer in any detail to the results of researches already dealt with in that Report. I can more usefully devote part of the time at my disposal to supplementing it with a review of more recent researches which have considerably extended our knowledge in many directions.

Ignition Phenomena.

The first Section of my 1910 Report was concerned with Ignition Temperatures and the Initial Phases of Gaseous Explosions, and it is in connection with ignition phenomena that subsequent progress has been most marked.

For the ignition of a given explosive mixture it is necessary that the temperature of its constituents should be raised, at least locally, to a degree at which a mass of gas self-heats itself by combination until it bursts into flame; or, in other words, to a degree at which the chemical action becomes autogenous or self-propelling, so that it quickly spreads throughout the whole mass. This particular degree, or in some cases range, of temperature is commonly spoken of as *the ignition-point* of the mixture, but in using the expression certain qualifications should be carefully borne in mind. In the first place, as H. B. Dixon and H. F. Coward had shown in 1909,[2] whereas when certain combustible gases (such, for example, as hydrogen and carbon monoxide, the mechanism of whose combustion is probably of a fairly simple character) and air or oxygen are *separately* heated in a suitable enclosure before being allowed to mix, the temperature at which ignition occurs lies within a very narrow

[1] *Brit. Assoc. Reports*, 1910 (Sheffield), pp. 469 to 505.
[2] *Trans. Chem. Soc.* 1909, vol. 95, pp. 514 to 543.

range, which is, within the limits of experimental error, the same for both air and oxygen (*i.e.*, in the case of hydrogen it is 580° to 590°, and for carbon monoxide 640° to 658°); on the other hand, in cases where the mechanism of combustion is known to be very complex (*e.g.*, hydrocarbons), the ignition range is either fairly wide or is materially lower in oxygen than in air (or both), thus :

—	In Air	In Oxygen
Methane . . .	650°–750°	556°–700°

The explanation of such behaviour is probably to be sought in the known complexity of the combustion, and the marked tendency for appreciable and fairly rapid interaction between the inflammable gas and oxygen before the actual ignition-point is reached.

If, by any means, such preliminary interaction could be entirely suppressed, or if, on the other hand, it be very rapid in character, the observed 'ignition-range' would be narrowed, as is actually the case with ethylene (542° to 547° in air and 500° to 519° in oxygen).

There are two other means by which an explosive mixture may be ignited; one is by adiabatic compression and the other, and most commonly employed of all, is by the passage of an electric spark.

The adiabatic compression of an explosive mixture was originally suggested by Nernst as a means of determining its ignition-point, provided always (1) that ignition is not produced locally whilst the main of the gas is still far below the true ignition temperature, and (2) that the piston of the apparatus does not move appreciably after the gas has been raised to its ignition-point. At the time of my 1910 Report, Falk,[3] in America, had applied the method in the case of hydrogen and oxygen mixtures, with results which, in the light of more recent work, would appear to have been misleading or erroneously interpreted. Thus, for instance, he found that, of all the mixtures of hydrogen and oxygen, the equimolecular H_2+O_2 mixture has the lowest ignition-temperature (514°), from which he concluded that the gases react initially to produce hydrogen peroxide rather than steam. Such a conclusion, which I believe to be erroneous, naturally directed attention to the experimental method involved.

The subject was promptly taken up here in Manchester by H. B. Dixon and his co-workers,[4] with the result that much new light has been thrown on the phenomena accompanying ignition. The ratio of the ignition-temperature to the initial temperature of the mixture before compression, both expressed in degrees absolute $\frac{T_2}{T_1}$, may be calculated from the compression ratio, $\left(\frac{V_1}{V_2}\right)$, by means of the well-known formula for adiabatic compression :

$$\left(\frac{T}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma - 1}$$

where γ = the ratio of the specific heats at constant pressure and volume respectively of the mixture compressed, and which for a mixture of diatomic gases, such as hydrogen and oxygen, is usually taken as 1.40.

Dixon's recent photographic analysis of the appearance of flame when mixtures of carbon bisulphide and oxygen (CS_2+3O_2) are adiabatically compressed, have proved that the flame, starting from a point or layer, always takes an appreciable time to spread through the mixture, and that unless special precautions are taken to arrest the piston at the moment of attainment of the ignition condition, it may be driven in much further than the minimum distance for ignition. The real ignition-point, as above defined, is not necessarily synchronous with the actual appearance of flame; there may be, and usually is, an

[3] *Journ. Amer. Chem. Soc.* **28**, 1517; **29**, 1536.

[4] H. B. Dixon, L. Bradshaw, and C. Campbell, *Trans. Chem. Soc.* 1914, **105**, 2027; H. B. Dixon and J. M. Crofts, *ibid.* p. 2036.

appreciable '*pre-flame period*'; only in the fastest burning mixtures is this period negligible, and hence the necessity of stopping the movement of the piston artificially at the beginning of the period, a precaution which Falk seems to have neglected.

According to Dixon and Croft's recent determination by this method of the ignition-points of mixtures containing electrolytic gas, whereas successive additions of hydrogen or nitrogen progressively raise the ignition-temperature of the undiluted gas by regular increments, as would be supposed, successive additions of oxygen, on the other hand, lower it, as a glance at the following table will show :

The Ignition points of Mixtures containing Electrolytic Gas by Adiabatic Compression.

By H. B. Dixon *and* J. M. Crofts, 1914.

Electrolytic Gas, $2H_2 + O_2 = 526°$		
$+ xH_2$	$+ xN_2$	$+ xO_2$
$x = 1$ . . . 544°	$x = 1$ . . . 537°	$x = 1$ . . . 511°
$x = 2$ . . . 561°	$x = 2$ . . . 549°	$x = 7$ . . . 478°
$x = 4$ . . . 602°	$x = 4$ . . . 571°	$x = 15$ . . . 472°
$x = 8$ . . . 676°	$x = 8$ . . . 615°	
$(526 + 18x)°$	$(526 + 11x)°$	

The observed raising effects of successive dilutions with hydrogen and nitrogen call for no comment, save that the relative greater effect of hydrogen, as compared with nitrogen, may be attributed to its greater thermal conductivity; but the lowering effect of oxygen is indeed puzzling, and its meaning can only be conjectured. Dixon and Crofts have suggested that it may be due either to the formation of some active polymeride of oxygen under the experimental conditions, which seems to me doubtful, or that the concentration of oxygen in some way or other brings about increased ionisation of the combustible gas. This at once raises the larger question of whether or not ignition is a purely thermal problem, as until recently has generally been supposed.

Professor W. M. Thornton, of Newcastle, has recently published some very suggestive work on the Electrical Ignition of Gaseous Mixtures,[5] which, quite apart from its theoretical interest, has an important bearing on the safety of coal-mines where electrical currents are used for signalling and other purposes.

The common belief that any visible spark will ignite a given explosive mixture of gas and air is, of course, quite erroneous, for, just as Coward and his co-workers have shown that for a given explosive mixture and sparking arrangement there is a certain limiting pressure of the gaseous mixture below which ignition will not take place, so from Thornton's work would it appear that a definite minimum of circuit energy is required before a given mixture at given pressure can be ignited by a spark. And, moreover, he has stated that the circuit energy required for the spark ignition of a given mixture say of methane and air is something like 56 times greater with alternating than with continuous current at the same voltage. From this he has argued that the igniting effect cannot be simply thermal, but must be in part at least ionic. This conclusion he has further supported with the statement that the igniting power of a unidirectional current is, in fact, proportional to the current in the case of many gaseous mixtures over an important part of their working range of inflammability.

While there is much that is suggestive in Thornton's work, there is also a good deal which seems very difficult to interpret from a chemical standpoint; I refer more particularly to his later supposition of 'stepped ignition,' which is based upon certain observed abrupt increases in the minimum igniting current required with condenser discharge sparks as the proportion of combustible gas

[5] *Proc. Roy. Soc.*, Sec. A, vol. 90 (1914), p. 272; *ibid.* vol. 91 (1914), p. 17

in the air mixture examined progressively increases. In other words, it is claimed that continuous alteration of the proportions of gas and air in an explosive mixture is, or may be, accompanied by discontinuous alterations in the spark energy required for ignition. I must confess that, after careful examination of the published curves, I am quite at a loss to give them any chemical interpretation, and to being somewhat sceptical about this supposed 'stepped ignition.'

A repetition and extension of Professor Thornton's experiments would be most valuable as a means to a better understanding of the conditions of spark-ignition.

The Influence of Electrons upon Combustion.

During the discussion upon my 1910 report, Sir J. J. Thomson reminded chemists that combustion is concerned not only with atoms and molecules but also with electrons moving with very high velocities. They might be a factor of prime importance in such intensive forms of gaseous combustion as are realised in contact with hot or incandescent surfaces, as also in the explosion wave. It is known, of course, that incandescent surfaces emit enormous streams of electrons travelling with high velocities, and the actions of such surfaces may be due to the formation of layers of electrified gas in which chemical changes proceed with extraordinarily high velocities. Again, the rapidity of combustion in the explosion wave might (he thought) conceivably be due to the molecules in the act of combining sending out electrons with exceedingly high velocities, which precede the explosion-wave and prepare the way for it by ionising the gas.

With regard to this interpretation of the action of surfaces, Mr. Harold Hartley carried out a promising series of experiments in my laboratory at Leeds University upon the combination of hydrogen and oxygen in contact with a gold surface,[6] which lend some support to the idea, but they require further extension before it can be considered as finally proved. It is my intention in the near future to resume the systematic investigation of the matter as rapidly as circumstances permit; but the experimental difficulties are formidable, and the mere chemist working by himself may easily be misled. We badly need the active co-operation of physicists in elucidating the supposed *rôle* of electrons in combustion.

Professor H. B. Dixon and his pupils have, at Sir J. J. Thomson's suggestion, recently tested the idea as applied to the explosion-wave, with, however, negative results.[7] It is known, of course, that the motion of the ions can be stopped at once by means of a transverse magnetic field, in which they curl up and are caused to revolve in small circles, and the question which Professor Dixon decided to put to the test of experiment was whether the damping of the electronic velocities in a powerful magnetic field would have any appreciable effect upon either the initial phase of an explosion or upon the high velocity of detonation. But although he employed a very intense magnetic field, produced by powerful magnets specially constructed by Sir Ernest Rutherford for the deflection of electrons of high velocity, no appreciable effect was observed upon the character or velocity of the flame with any gas mixture at any stage of the explosion And inasmuch as the high constant velocity of the explosion wave can be entirely accounted for on the theory of a compression-wave liberating the chemical energy as it passes through the gases, there seem to be as yet no experimental grounds for attributing it to the ionising action of electrons.

The Initial Period of 'Uniform Movement of Flame' through Inflammable Mixtures, and Limits of Inflammability.

Mallard and Le Chatelier, in their classical researches upon the combustion of explosive mixtures,[8] discovered that the propagation of flame when such a mixture is ignited in a horizontal tube differs according as whether the ignition

[6] *Proc. Roy. Soc.* 1914.
[7] *Proc. Roy. Soc.* 1914, Sec A, vol. 90, p. 506.
[8] *Ann. des Mines*, 1883 (8) 4, 274.

occurs near the open or closed end of the tube. In the first case, the flame proceeded for some distance down the tube at a practically uniform and fairly slow velocity, corresponding to the true rate of propagation 'by conduction'; this period of uniform movement is succeeded by an irregular oscillatory period, in which the flame swings backwards and forwards with increasing amplitudes, finally either dying out altogether or giving rise to detonation. With certain oxygen mixtures the initial period of uniform slow velocity was shorter and appeared to be abruptly succeeded by detonation, without the intervention of any oscillatory period. When, however, such mixtures were ignited near the closed end of a horizontal tube, the forward movement of the flame was continuously accelerated from the beginning, under the influence of reflected compression waves, until detonation was set up. Such, in general, was the sequence of the phenomena observed by these distinguished French investigators.

They proceeded to determine experimentally the velocities of the uniform slow movement of the flame in the case of a number of air and combustible gas-mixtures, and plotting their results (in cm. per sec.) as ordinates against percentages of inflammable gas as abscissæ, they obtained 'curves' which were in each case formed of two inclined straight lines converging upwards to a point which represented the composition and flame-velocity of the most explosive mixture. And they concluded that the points at which the downward production of the two lines met the zero velocity line would define the upper and lower limits of inflammability for the particular series of gas-air mixtures Thus the curve they obtained for methane-air mixtures (fig. 1) showed a maximum velocity of 61 cm. per second for a mixture containing about 12·2 per cent. of methane, with lower and upper limits corresponding to 5·6 and 16·7 per cent. of methane, respectively.

An exact knowledge of the velocities of flame-propagation during this initial period of uniform slow movement, as well as of the limits of inflammability for mixtures of various combustible gases and air, is very important from a practical point of view. Makers of apparatus for burning explosive mixtures of gas and air want to know the speed of flame-propagation through such mixtures, not only at ordinary temperatures and pressures, but also when the mixtures are heated and used at higher pressures. Also it would be important to know whether or not in the case of a complex mixture of various combustible gases and air, where complete composition can be determined by analysis (as, for example, coal-gas and air), the velocity of flame-propagation can be calculated from the known velocities for its single components Unfortunately, although more than thirty years have elapsed since Mallard and Le Chatelier's work was published, the necessary data are still wanting to answer such questions, and anyone who will systematically tackle the problem and carefully work it out in detail will be doing a real service to the gas-using industries. I am hoping shortly to make a beginning with such an investigation in my new Department at the Imperial College, London, but the successful and rapid progress of such work will involve considerable financial outlay as well as organisation and expert direction. Who will help us with the necessary funds?

An accurate knowledge of the behaviour of methane-air mixtures under known variations of conditions is of prime importance from the point of view of the safety of coal-mines, and it is rightly occupying the attention of my friend and former collaborator, Dr R. V. Wheeler, at the Home Office Experimental Station at Eskmeals. And from papers which he has already published, as well as from some unpublished results which he has very kindly permitted me to refer to in this Address, it is now possible to correct certain errors in Mallard and Le Chatelier's results, and to arrive at a clearer view of the phenomena as a whole.

In the first place, it would appear that the initial 'uniform movement' of flame in a gaseous explosion, or, in other words, propagation of the flame from layer to layer by conduction only (as defined by Le Chatelier), is a limited phenomenon, and is only obtained in tubes of somewhat small diameter, wide enough, however, to prevent appreciable cooling of the flame, but narrow enough to suppress the influence of convection currents Moreover, ignition must be either at, or within one or two centimetres of, the end of the tube, or

otherwise—particularly with the more rapidly moving flames—vibrations may be set up from the beginning.

Whilst all methane-air mixtures develop an initial uniform slow flame-movement period when ignited at or near the open end of a horizontal tube, both its linear duration as well as the flame velocity are not, according to private information which Dr. Wheeler has sent me, independent of the dimensions of the tube (*vide* fig. 2). The speed of flame increases with the diameter of the tube, and the linear duration of the uniform period increases with both the diameter and length of the tube up to a certain maximum, after which increase in length probably makes no appreciable difference; also, for the same tube, it varies with the proportion of methane in the explosive mixture, being greater as the speed of the flame diminishes, until with the two 'limiting' explosive mixtures it appears to last almost indefinitely.

Dr. Wheeler's recent redetermination of the velocities of the flame move-

RATE OF INFLAMMATION.

(*Le Chatelier.*)

METHANE AND AIR.

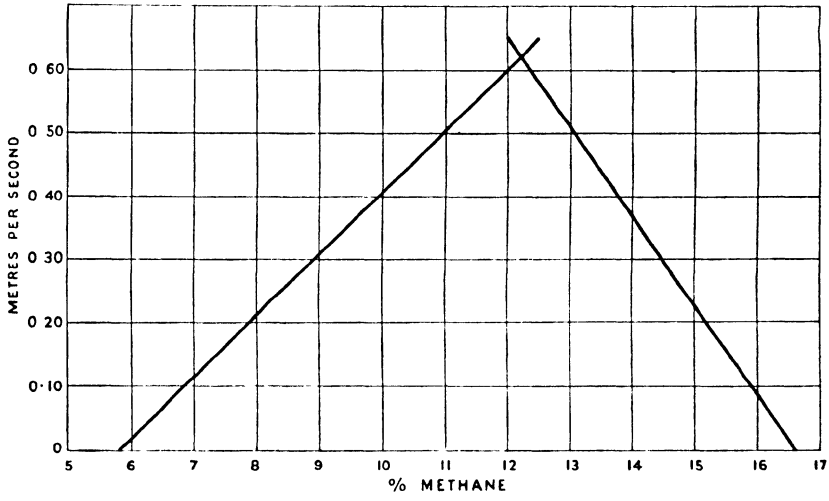


FIG. 1.

ment during this initial uniform period for mixtures of methane and air in varying proportions within the limits of inflammability has revealed serious errors in Mallard and Le Chatelier's original results for horizontal tubes of the same diameter as those which Dr. Wheeler has employed. Moreover, Mallard and Le Chatelier's method of determining the composition of the upper and lower limits of inflammability by extrapolation from their curves has been proved to be unwarranted. Dr. Wheeler considers that the length of the tubes used by Mallard and Le Chatelier (1 mètre only) was insufficient to ensure that the speed measurements of its initial uniform flame-movement period were unaffected by the subsequent 'vibratory period.' Also, the methane used by them, prepared as it was from sodium acetate, would obviously be impure.

The most important differences between the latest results published by Dr. Wheeler and those originally determined by Mallard and Le Chatelier, as shown on the accompanying diagram (fig. 3) are as follows:

(1) According to Wheeler, the limits of inflammability for horizontal propagation of flame in methane-air mixtures, at atmospheric temperature and pressure, correspond to 5·4 and 14·3 per cent. methane contents, respectively, whereas Mallard and Le Chatelier gave 5·6 and 16·7 per cent.

(2) Whereas, according to Mallard and Le Chatelier, the flame velocities for mixtures near the upper and lower limits would gradually approximate to the zero velocity ordinate, as the limiting composition was approached, according to Wheeler the velocities for both the upper and lower limiting mixtures are considerable (in each case about 36 cm. per sec.), and there is an abrupt change from these velocities to zero velocity as the particular limiting composition is passed.

Dr. R. V. Wheeler on Speeds of Uniform Movement of Flame through Methane-Air Mixtures in Tubes of Different Diameters.

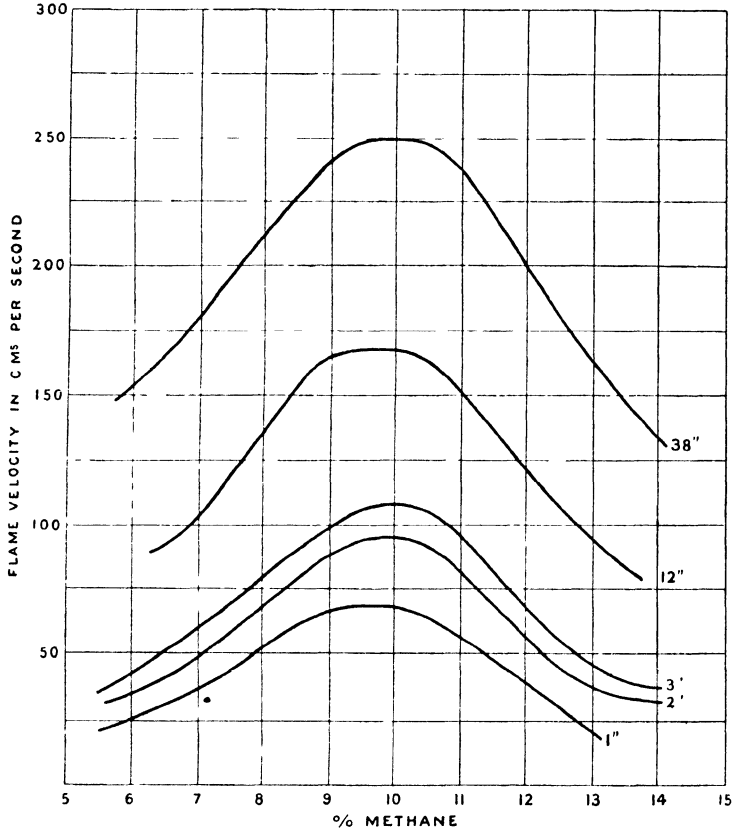


FIG. 2.

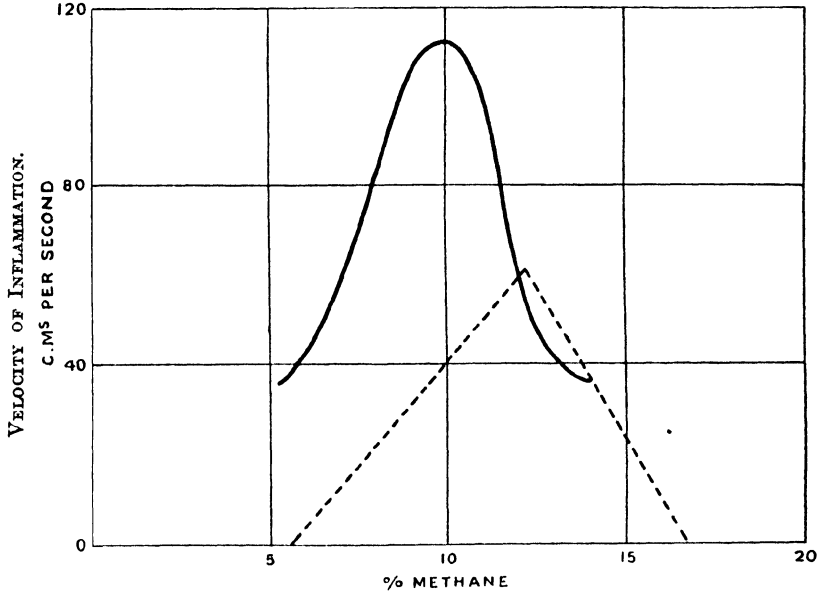
(3) Whereas Mallard and Le Chatelier found a maximum velocity of 63 cm. per sec. for a mixture containing about 12·2 per cent. of methane, and a rapid falling off in velocity as this particular composition is deviated from, Wheeler finds a maximum velocity of 110 to 112 cm. per second for a series of mixtures containing from 9·45 to 10·55 per cent. of methane. Such differences as are thus disclosed only emphasise the need of a complete experimental revision of the subject.

Messrs. Burgess and Wheeler have recently determined the limits of inflammability of methane when mixed, at atmospheric temperature and pressure, with 'atmospheres' of oxygen and nitrogen containing less oxygen than ordinary air. From their results (see table, fig. 3) it would appear that as the oxygen content

of the atmosphere is reduced, the limits of inflammability are narrowed until they coincide when the oxygen content falls below 13·3 per cent., which means that an atmosphere containing 13·3 or less per cent. of oxygen is truly extinctive for a methane flame at ordinary pressures.

Atmosphere		Methane per cent.	
Oxygen	Nitrogen	Lower Limit	Higher Limit
20·90	79·10	5·60	14·82
17·00	83·00	5·80	10·55
15·82	84·18	5·83	8·96
14·86	85·14	6·15	8·36
13·90	86·10	6·35	7·26
13·45	86·55	6·50	6·70

My review of this part of the subject would be incomplete without a reference to some interesting observations which have been made by Dr. H. F. Coward and co-workers at the Manchester School of Technology upon the behaviour of weak mixtures of various inflammable gases and air at or just below the lower limit of inflammability in each case.[1] Their principal experiments were carried out in a rectangular box of 30 cm. square section and 1·8 metres length, with two opposite sides of wood, and the other two of plate glass The box was placed in an upright position, the bottom being water-sealed and the



Burgess and Wheeler ———
Mallard and Le Chatelier .....

FIG. 3.

top closed, with a suitable igniting device near the bottom. They have shown that caps or vortex rings of flame may be projected for some distance upwards from the source of ignition, sometimes apparently for an indefinite distance, without igniting the whole of the combustible mixture. In such mixtures

[1] *Trans. Chem. Soc.* 1914, **105**, p. 1859.

there may be an indefinite upward slow propagation of flame together with incompleteness of combustion (much of the combustible mixture remaining unburnt), and the question naturally arises as to how the term 'inflammability' should be scientifically defined. Dr. Coward has argued with some force that a gaseous mixture should not be termed 'inflammable' at a given temperature and pressure unless it will propagate flame indefinitely, the unburnt portion being maintained at that temperature and pressure Inflammability, thus defined, would be a function of the temperature, pressure, and composition of a particular mixture only and would be independent of the shape and size of the containing vessel; and, provided that it is kept in mind that for each particular mixture at a given temperature and pressure a certain minimum igniting energy and intensity is requisite, I am inclined to agree with the definition. Also, there is the possibility that in a mixture just at or very near one or other of the limits of inflammability flame may be propagated *upwards* but not *downwards*.

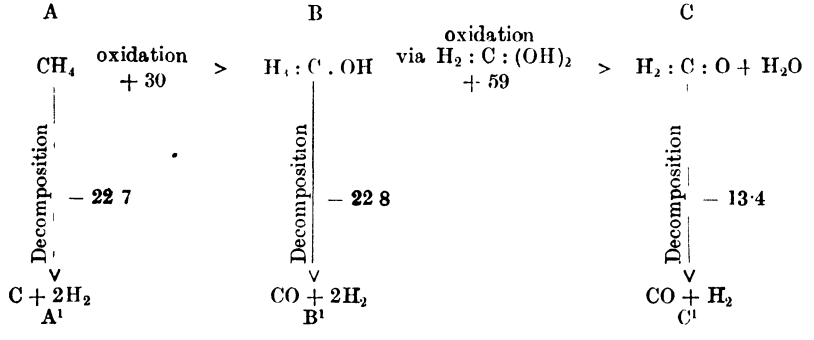
From his experiments Dr. Coward has assigned the following as the lower limits of inflammability of hydrogen, methane and carbon monoxide, respectively, in air at atmospheric temperature and pressure :

	Per cent.
Hydrogen	4·1
Methane	5·3[10]
Carbon monoxide	12·6

The Combustion of Hydrocarbons and the Relative Affinities of Methane, Hydrogen, and Carbon Monoxide, respectively, for Oxygen in Flames.

Under the title of 'Gaseous Combustion at High Pressure' I have recently published, in conjunction with various collaborators,[11] a further instalment of my researches upon the mechanism of hydrocarbon combustion,[12] and I may perhaps be allowed to draw your attention to certain new points which have arisen in connection therewith.

A detailed study of the behaviour of mixtures of methane and oxygen of composition ranging between $2CH_4 + O_2$ and $CH_4 + O_2$, when exploded in steel bombs at initial pressures of 12·7 atmospheres (see table, fig 4), has shown it to be consistent with the 'hydroxylation' theory of hydrocarbon combustion which I put forward some years ago as the result of my previous work. The following scheme seems to interpret correctly the chemical and thermal changes involved in the initial stages of the explosive combustion of methane :



[10] Too much stress need not be laid upon the difference between this number and the 5·6 per cent. given by Dr. Wheeler (*loc. cit.*), because Dr. Coward himself admits that the flames of mixtures containing from 5·3 to 5·6 per cent. of methane are very sensitive to shock, whilst a 5·6 per cent. mixture will always propagate flame indefinitely even when there is a moderate disturbance; the conditions must be exceedingly tranquil to prevent extinction in the other cases.

[11] Messrs. Hamilton Davies, H. H. Gray, H. H. Henstock, and J. B. Dawson.

[12] *Phil. Trans. Roy. Soc.*, A., vol. 215 (1915), pp. 275 to 318.

Explosion of Mixtures of varying Composition between $2CH_4 + O_2$ *and* $CH_4 + O_2$ *in Bomb at Initial Pressure 12·7 atmospheres.*

Experiment No.	10			11			12			13		
Pressures in atmospheres p_1	12·74			12·72			12·68			12·61		
Pressures in atmospheres p_2	15·05			18·10			17·30			14·10		
p_2/p_1	1·18			1·42			1·36			1·12		
	Per cent.	Partial Pressures, Atmospheres		Per cent	Partial Pressures, Atmospheres		Per cent.	Partial Pressures, Atmospheres		Per cent.	Partial Pressures, Atmospheres	
Original mixture CH_4	67·15	8·55		59·3	7·54		55·75	7·09		50·8	6·40	
Original mixture O_2	32·85	4·19		40·7	5·18		44·25	5·59		49·2	6·21	
	Per cent.	Partial Pressures, Atmospheres		Per cent	Partial Pressures, Atmospheres		Per cent.	Partial Pressures, Atmospheres		Per cent.	Partial Pressures, Atmospheres	
Gaseous products CO_2	3·10	0·47		2·70	0·49		3·85	0·67		7·45	1·05	
Gaseous products CO	25·40	3·83		35 60	6·44		37·25	6·44		38·50	5·44	
Gaseous products CH_4	16·60	2·50		4·65	0·84		2·25	0·39		nil	nil	
Gaseous products H_2	54·90	8·26		57·05	10·32		56·65	9 80		54·05	7·60	
	C.	H.	O.	C.	H.	O.	C.	H.	O	C.	H.	O.
Units in original mixture	8·55	17·10	4·19	7·54	15 08	5·18	7·09	14 18	5 59	6·40	12·80	6·21
Units in gaseous products	6·80	13·26	2·38	7·77	12 00	3·71	7·50	10·58	3 89	6·49	7·60	3·77
Difference atmospheres	1·70	3·84	1·81	—	3·08	1 47	—	3·60	1·70	—	5·20	2·44
Difference per cent.	20		43·2			28·4			30·4			38·2
Ratio $\frac{CO \times OH_2}{CO_2 \times H_2}$ in products	3·65			3·75			3·43			3·4		
Remarks	Explosion almost inaudible; carbon deposited.			Explosion distinctly audible.			No carbon deposited.			Very violent explosion with sharp metallic click. No carbon deposited.		

FIG. 4.

The principal experimental facts which this, or indeed any alternative, scheme must explain are as follows :

(1) That whenever mixtures of composition between $2CH_4+O_2$ and CH_4+O_2 are exploded under pressure a considerable proportion of the original oxygen appears as steam in the products;

(2) That there is a marked *minimum* in the proportion of such oxygen as the composition of the original mixture approximates to $3CH_4+2O_2$; and

(3) That there is a total cessation of any separation of carbon (which is very marked with mixtures $2CH_4+O_2$) after the proportion of oxygen in the original mixture attains or exceeds the limit $3CH_4+2O_2$.

Now, if, as I believe, the initial interaction of methane and oxygen is at all temperatures essentially a 'hydroxylation' process, accompanied by the decomposition (more or less rapid according to the temperature) of the primarily formed hydroxylated molecules, a consideration of the chemical and thermal aspects of the process will point to certain probabilities which are indeed actually realised in fact.

In the first place, monohydroxymethane (methyl alcohol) $CH_3.OH$ is known to decompose at high temperatures, yielding carbon monoxide and oxygen, without any separation of carbon or formation of steam, $CH_3.OH=CO+2H_2$. Also, the very unstable dihydroxy methane, $H_2:C:(OH)_2$ would yield formaldehyde and steam, $H_2:C:(OH)_2=H_2:C:O+H_2O$, and the formaldehyde would in turn decompose into carbon monoxide and hydrogen, $H_2:C:O:=CO+H_2$, without any deposition of carbon whatever.

If now the thermal consequences of such facts be considered, it would appear (1) that if the oxidation of methane to $H_2:C.OH$ (A to B in the scheme) were accompanied by thermal decomposition at this stage (B to B^1), the *net* heat evolution would be $(30-22{\cdot}8)=7{\cdot}2$ kilogram Centigrade units; whereas (2) if the same amount of oxygen reacted in such a way that there was a 'non-stop' run through the *monohydroxy-* to the *dihydroxy-* stage, with decomposition at the point (A to C and C to C^1), the corresponding net heat evolution would be $\frac{1}{2}(30+59-13{\cdot}4)=37{\cdot}8$ units, or about five times as much as in (1). Hence there would always be a strong tendency for such a non-stop run from A to C through B, without any decomposition occurring at B, and such would always occur whenever the oxygen present in the original mixture attained the equimolecular proportion CH_4+O_2.

Again, if the original mixture contained only half such proportion of oxygen ($2CH_4+O_2$), there would still be a decided preference for an oxidation of one-half of the methane by a non-stop run A to C through B, rather than an oxidation of the whole of the methane to B only, the other half of the methane remaining unchanged, or undergoing thermal decomposition into its elements, $CH_4=C+2H_2$ (A to A^1). Also, the latter process would use up no more of the energy developed from the oxidation than would be required for the decomposition of a corresponding quantity of $H_2:C.OH$ at stage B (B to B^1). Hence when such a mixture, $2CH_4+O_2$, is exploded under pressure, the formation of carbon and its oxides, hydrogen, and considerable quantities of steam may be expected, which is what actually occurs.

When, however, the proportion of oxygen in the original mixture reaches the limit $3CH_4+2O_2$, whilst it is still insufficient to oxidise the whole of the hydrocarbon to the *dihydroxy-* stage, there is enough of it to prevent any methane remaining unoxidised to (at least) the *monohydroxy-* stage, and, therefore, seeing that the affinity of methane for oxygen far exceeds those of either hydrogen or carbon monoxide, it is to be expected that no substantial proportion of the original methane would escape oxidation to either the *mono-* or the *dihydroxy-* stage. But inasmuch as not more than about one-third of the original methane could, in the circumstances, be transformed into the di-hydroxy- stage, it follows that a considerable amount of thermal decomposition at the mono-hydroxy- stage would occur.

If this view is correct, it follows that there should be an entire suppression of carbon deposition at or about the $3CH_4+2O_2$ ratio, and, also, that with this

particular mixture a smaller proportion of the original oxygen should appear as steam in the products than would be the case with either the $2CH_4+O_2$ or the CH_4+O_2 mixture, which again is precisely what we find.

In considering the question of the explosive combustion of hydrocarbons it is important to distinguish between (1) the primary oxidation of the hydrocarbon, which is an exceedingly rapid process and is probably completed during the short interval between ignition and the attainment of maximum pressure, and (2) certain probable secondary interactions where influence may extend far into the subsequent cooling period, for it is only this latter which would be affected by variations in the rate of cooling down from the maximum temperature. Such secondary interaction may include (*a*) the reversible change $CO+OH_2 \rightleftharpoons CO_2+H_2$ and, in cases where carbon is deposited as the result of the decomposition of primary oxidation products, the interaction of steam and carbon $C+OH_2=CO+H_2$. In this connection, I may draw attention to the recently published work of G. W. Andrew,[13] one of my former pupils and collaborators, on the 'Water Gas Equilibrium in Hydrocarbon Flames' which proves that in a system containing only CO_2, CO, H_2, H_2O, rapidly cooling down from the high temperatures prevailing in hydrocarbon flames, the equilibrium ratio $\frac{CO \times OH_2}{CO_2 \times H_2}$ adjusts itself automatically with the temperature until a point between 1500° and 1600° C. on the cooling curve is reached (corresponding to a value $K=4{\cdot}0$ approximately), after which no further readjustment occurs. He also found that this adjustment of equilibrium is not greatly influenced even when relatively large quantities of methane and carbon are found in the final products.

I am able, from my own experiments, to confirm Andrew's conclusions in all cases where the initial firing pressure is insufficient to set up detonation; but, in cases where both detonation and separation of carbon occur, my results undoubtedly indicate an appreciable intervention of the separated carbon during the cooling period. There is nothing in my results, however, suggestive of an appreciable intervention of methane.

The fact that the primary oxidation of methane usually involves a direct transition from CH_4+O_2 to $CH_2(OH)_2$, which latter breaks up into, ultimately, $CO+H_2+H_2O$, without any deposition of carbon, opened up the possibility of instituting a direct experimental comparison between the relative affinities of methane and hydrogen for oxygen in explosions by exploding a series of mixtures $CH_4+O_2+xH_2$ in which the hydrocarbon and oxygen were initially present in as nearly as possible equimolecular proportions, but in which x (the volume ratio of H_2 to CH_4) was varied between 2 and 8, and determining (1) the oxygen distribution on explosion when $x=2$, and (2) the influence upon such distribution of successive equal increments of x up to 8.

Ever since Davy's experiments on Flame, the combustibility of hydrogen has been erroneously considered to be superior to that of methane; but, on the other hand, my previous researches upon hydrocarbon combustion have shown (1) that in slow combustion in borosilicate glass bulbs at temperatures between 300° and 400° C. methane, ethane, and acetylene are all oxidised at a much faster rate than is either hydrogen or carbon monoxide; and also (2) that in exploding such mixtures as $C_2H_4+H_2+O_2$ or $C_2H_2+2H_2+O_2$ the hydrocarbon is burnt in preference to hydrogen, facts which are at variance with any notion of the superior affinity of hydrogen for oxygen in flames.

My further experiments upon the relative affinities of methane and hydrogen for oxygen in explosives were carried out at high initial pressures in two special steel bombs, namely, A, with a cylindrical explosion chamber 8 inches long and 1 inch in diameter (capacity = *circa* 103 c.c.), and, B, with a spherical cavity 3 inches in diameter (capacity = *circa* 275 c.c.). The ratio of wall surface of the explosion chamber in the case of Bomb A would thus be about 2·75 times that of Bomb B. The mean results obtained for the distribution of oxygen

[13] *Trans. Chem. Soc.* 1914, **105**, pp. 444 to 456.

between methane and hydrogen in the two sets of experiments were as follows :

Distribution of Oxygen when Mixtures $CH_4+O_2+xH_2$ *are exploded.*

x		2	4	6	8
		%	%	%	%
Bomb A	O_2 to CH_4	95·34	81·0	54·9	31·4
	O_2 to H_2	4·66	19·0	45·1	68·6
Bomb B	O_2 to CH_4	97·1	91·0	72·6	—
	O_2 to H_2	2 9	9·0	27·4	—

It is at once evident from the results with the mixture $CH_4+O_2+2H_2$ that the affinity of methane is at least twenty to thirty times greater than that of hydrogen for oxygen in explosion flames. The actual distribution of oxygen when a particular mixture is exploded is undoubtedly influenced to some extent by the walls of the containing vessel, but not, so far as I have been able to ascertain, by the absolute initial pressure. Moreover, it is evident that the influences of successive increases in x, the volume ratio of H_2 to CH_4 in the mixture exploded, upon the actual oxygen distribution for a given explosion is proportionate to x^2, which can hardly mean other than that in explosion flames hydrogen is *directly* burnt to steam, and not, as many have supposed, *via* the intermediate formation of hydrogen peroxide.

A similar series of experiments with mixtures CH_4+O_2+xCO show that whilst it is impossible, owing to circumstances which I need not here detail, to deduce, even approximately, any numerical relation between the affinities of methane and carbon monoxide for oxygen in flames, yet we can confidently say that the affinity of the hydrocarbon is again vastly the superior, although carbon monoxide is apparently more effective than hydrogen in pulling away oxygen from the predominating attraction of methane.

Having thus satisfactorily disposed of the question of relative affinities of the three gases for oxygen in explosion flames, it remained to prove whether or not such chemical factors determine the ratio of attainment of maximum pressure in explosions, by exploding mixtures of each of the three combustible gases with air, in such proportions as correspond with the primary oxidation, namely : (1) $CH_4+O_2+4N_2$, (2) $2H_2+O_2+4N_2$, and (3) $2CO+O_2+4N_2$, at initial pressure of from 45 to 50 atmospheres in the spherical Bomb B to which was attached a Petavel recording manometer with its optical accessories.

The pressure records which are reproduced in the following diagrams (figs. 5, 6, and 7), in which pressures in atmospheres are plotted against time in seconds, prove conclusively the absence of any direct relation between the

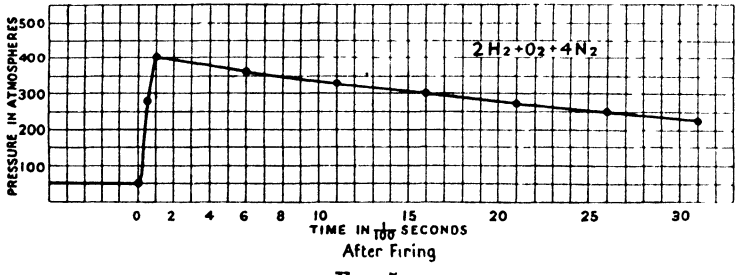


FIG. 5.

actual rate at which the potential energy of an explosive mixture is transferred on explosion as sensible heat to its products and the magnitude of the chemical affinity between its combining constituents. This is hardly to be wondered at,

seeing the extreme rapidity of chemical interaction at high temperature as compared with the rate at which the liberated heat can be communicated to and uniformly distributed amongst the products by ordinary physical processes. Attention may be drawn to the extreme slowness of the cooling in each case after the attainment of maximum pressure; this has also been observed by

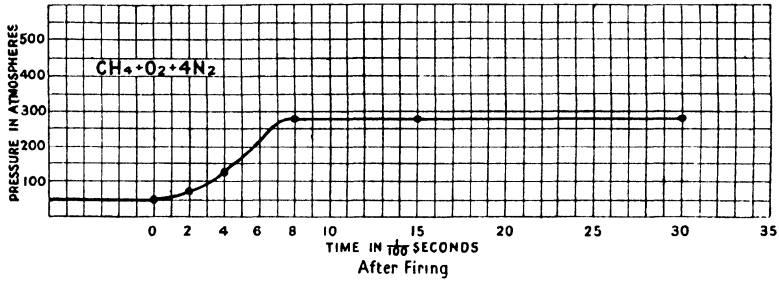


FIG. 6.

previous workers in other similar cases of gaseous explosions. This was particularly marked in the case of the methane-air mixture, in which there was hardly any appreciable cooling during an interval of 0·22 seconds after the attainment of maximum pressure (in 0·08 sec.), a circumstance which may be due in part to the combustion taking place in well-defined chemical stages, and

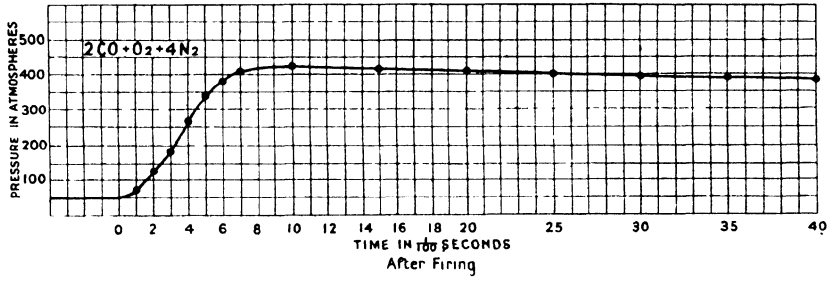


FIG. 7.

in part also to the operation of the exothermic secondary interaction between carbon monoxide and steam during the cooling period. On the other hand, the curve for the hydrogen-air mixture, where the combustion to steam is a direct and comparatively simple transaction, suggests that the attainment of maximum pressure is succeeded by a period of gradual cooling uninfluenced by chemical combination.

Fuel Economy and the Proper Utilisation of Coal.

Leaving now the scientific aspects of flame and combustion I wish to say a few words, as a technologist, upon the great national importance of a more adequate scientific control of fuel consumption and the utilisation of coal generally, with special reference to the situation created by this terrible and ruinous European conflict. And my remarks will be addressed in part to my chemical friends and colleagues, who are primarily interested in scientific research and its industrial applications, and in part also to the commercial and manufacturing community, which is chiefly interested in the financial results of such scientific activity.

Notwithstanding the fact that we are raising annually in the United Kingdom (according to the official estimate for 1913) 287 million tons of coal,

of which 189 million tons (or, say, 4 tons per head of population) were consumed at home more or less wastefully, it is indeed surprising how little has been done, or is being done, by the scientific community to impress upon the Government and the public generally the importance of establishing some systematic control or investigation of fuel consumptions in all large industrial areas. Deputations have waited upon the Government about the question of reviving our languishing coal-tar colour industry, so that in future we may be independent of Germany for the supply of the two million pounds' worth of dye-stuffs required by our textile industries, and already a State-aided organisation, with an advisory scientific committee, has sprung into existence to achieve that desirable result. But no organised body of scientific men, so far as I know, has ever thought it important, or worth while, to take an active interest in the vastly greater subject of fuel economy and the proper utilisation of coal, upon which the dyeing industry depends for its raw materials.

It is unnecessary for me to remind you that the contending armies in this Armageddon of the nations depend upon certain distillation products of coal for their supplies of high explosives, and there is little doubt in my mind but that Germany's violation of the neutrality of Belgium, and her subsequent seizure of that country and of a large tract of Northern France, had more than a purely political or strategic significance. She doubtless wanted also to seize for herself, and at the same time to deprive her enemies of, coal-fields lying just beyond her own borders, which are capable of furnishing abundant supplies of coal admirably adapted for yielding the raw materials for the manufacture of high explosives. A country in which all metallurgical coke has for years past been manufactured under chemical supervision in by-product coking ovens with recovery of ammonia, tar, and benzol, and in which the wasteful beehive coking ovens have long ago ceased to exist, was hardly likely to overlook the military importance of the Belgian coal-field with its many by-product coking plants. And, moreover, but for German commercial acumen and enterprise, during many years past, our own by-product coking industry would not have attained even to its present respectable dimensions. Certainly, it owes very little to the interest or attentions of British chemists, most of whom are, unfortunately, but little aware of its circumstances and conditions, and seem to care even less for its particular problems. And yet in proportion to the capital outlay upon it, it is one of the most profitable of all our chemical industries, coal-tar colour-making not excepted

Fuel economy, and the proper utilisation of coal, whether in connection with manufacturing operations or with domestic heating, will become one of the most important national questions during the trying years that will follow hard upon this war, because, of all directions in which national economy can be most healthfully and advantageously exercised, this is perhaps the most obvious and prolific. For it is tolerably certain that with an efficient and systematic public supervision of fuel consumptions we ought to be able, even with existing appliances, to save many millions of pounds of our annual coal-bill, and with improved appliances still more millions, a saving which would in the long run redeem a considerable amount of the War-loan, which has been much more easily raised than it will be repaid.

Now, I fear that not only are chemists for the most part lamentably ignorant of the nature of coal, and of modern fuel technology, but they have been for many years past so indifferent about such questions as to leave them almost entirely to engineers, who, as a body, are notoriously deficient in chemical sense and experience. The engineer has indeed not usurped the place of the chemist, but has had to do his best to fill the position long since abdicated by the chemist.

This, indeed, seems strange when we remember that the foundations of modern chemistry were deeply laid by investigators who were, above all things, 'fire-worshippers.' But, judging from most chemical text-books, nearly all that the modern student of chemistry is taught in our academies about combustion was known to Lavoisier, and I question whether in the majority of our university laboratories any investigation upon coal or combustion is ever undertaken. And yet the subject is full of the most fascinating and fundamental theoretical problems, for the most part unsolved, and the nation consumes every week as much coal as could be exchanged for the whole quantity of aniline dyes used by its textile industries in a year.

Moreover, such advances as have been made during recent years, and they are by no means inconsiderable, have nearly all been in the direction of the wider applications of gaseous fuels, yet in how many of our University laboratories is even gas analysis taught, or how many of our Schools of Chemistry provide systematic courses in the chemistry and manipulation of gases, without which no professional training of industrial chemists, however much 'research work' it may include, ought to be considered satisfactory? It is my opinion that this important branch of our chemical craft and science has not, for many years past, been accorded its proper place and share of attention in the ordinary curriculum of the majority of our academic institutions.

Of the 189 millions of coal consumed in the United Kingdom in the year 1913, about 40 million tons, or say approximately one-fifth of the whole, was carbonised either in gasworks, primarily for the manufacture of town's gas, or in coke ovens, for the manufacture of metallurgical coke, in practically equal proportions. Two-thirds of the latter was carbonised in by-produce recovery plants, the remainder in the old wasteful beehive ovens.

So that, roughly speaking, we have

Total Coal Carbonised = 40 million tons		
In Gasworks	In By-product Coke Ovens	In Beehive Coke Ovens
20	13·5	6·5

At the present moment there are 8.297 by-product coke ovens built in this country, or which 6,678 are fitted with benzol recovery arrangements, capable of producing in all something like 10 million tons of coke per annum.

The yields of the various by products obtainable on such coke-oven installations naturally vary with the locality and character of the coal-seam, but they probably average out somewhat as follows, expressed as percentages on dry coal carbonised :

District	Ammonium Sulphate	Tar	Benzol and Toluol as Finished Product
Durham . .	0·9 to 1·45	2·5 to 4·5	0·6 to 1·0
Yorkshire . .	1·3 to 1·5	3·5 to 5·0	0·9 to 1·1
Derbyshire . .	1·3 to 1·6	3·5 to 5·0	0·9 to 1·1
Scotland . .	1·4 to 1·6	3·5 to 5·0	0·9 to 1·1
South Wales .	0·9 to 1·1	2·0 to 3·5	0·6 to 0·75

or, to put the matter a little differently, each ton of dry coal carbonised yields from 20 to 35 lb. of ammonium sulphate, from 56 to 112 lb. of tar, and from 2 to 3½ gallons of crude benzol, &c., according to the locality. About 65 to 70 per cent. of the crude benzol is obtained as finished products (benzene, toluene, solvent, and heavy naphthas).

How rapid has been the development of the by-product coking industry in this country during recent years may be judged from the following official returns of the quantities of ammonium sulphate annually made on such plants, as compared with the corresponding quantities produced in gasworks.

Year	Tons of Ammonia Sulphate produced in	
	By-product Coke Oven Plants	Gasworks
1903 . . .	17,435	149,489
1908 . . .	64,227	165,218
1913 . . .	133,816	182,180

In the natural course of events, the final disappearance of the wasteful beehive coke-oven from this country is now only a matter of a few years; but I venture to suggest that public interest would justify the Government fixing by law a reasonable time-limit beyond which no beehive coke-oven installation would be allowed to remain in operation, except by express sanction of the State, and then only on special circumstances being proved.

There is also much need of a better and more systematic chemical control, in the public interest, of by-product coking plants. At present, in far too many cases, the chemists employed in coke-oven laboratories are men who have practically no chemical training other than that obtained in evening classes. And, with few exceptions, the chemist, however competent he may be, is entirely subordinated to the directing engineer, and regarded as a mere routine analyst. I can say from personal knowledge that plants which are managed and controlled by experienced chemists of broad training, combined with force of character, yield much better results than those controlled by men without such qualifications.

And even in this crisis, when so much depends on plants working, not only at their maximum output capacities but also, chemically speaking, under conditions calculated to ensure the highest yields of benzol and toluol, with a proper selection of coal, I doubt whether the measures which have been taken to advise and supervise the coke-oven industry are really adequate from the point of view of chemical control. I do know, for instance, that the experience and resources of the majority of our University Departments of Applied Chemistry, which specialise on Fuel Technology and cognate matters, have not been as fully utilised as they might and ought to have been in this connection. I cannot for one moment imagine a similar state of things being permitted in Germany, where we may be sure that nothing is being left undone in the way of fully utilising all the available expert chemical and engineering knowledge which can be brought to bear on this important aspect of war munitions, and I will venture to say that, whatever may be the case in this country, in Germany at least the staff and resources of no publicly maintained Department of Fuel Technology will not be fully employed on War problems.

The coal-gas industry, which deals with some 20 million tons of coal per annum, has, especially within recent years, shown a growing appreciation of the aid of chemical science, in regard not only to the actual manufacture, but also to the domestic and industrial uses of coal-gas. The endowment in 1910 by the industry of a special Chair at Leeds University in memory of the late Sir George Livesey, of which I had the honour of being the first occupant, was a sure sign of the faith of its leaders in the value of scientific research into its special problems, and from personal knowledge and intercourse with gas engineers I can assure my chemical colleagues that any serious interest taken by scientific chemists in these problems, or in training men to tackle them, will be welcomed by the industry, no matter from what quarter such help or interest may come. For although the carbonisation of coal in gasworks is efficiently carried out, no one in the industry supposes that finality has been reached, or that existing methods and conditions cannot be improved under better chemical control.

And, moreover, the gas industry has just recently given a striking example of the public benefit which may accrue from the wholehearted co-operation of the chemist and engineer in the new nickel-catalytic process for the removal of carbon bisulphide from coal-gas, which has been worked out and brought to a successful issue by the combined skill and efforts of Dr. Charles Carpenter, Mr. D. Gibb, and Mr. Evans, of the South Metropolitan Gas Company. They have shown that the sulphur content (as CS_2) of London coal-gas can be reduced on a large scale, in regular day-to-day working, from nearly 40 drm. to about 8 grains per 100 cubic feet, without in any way deteriorating the quality of the gas, at a cost (including interest and depreciation) of 0·299*d* per 1000 cubic feet. Such a striking success was, as Dr. Charles Carpenter acknowledges, only achieved 'because of the unrestricted and unreserved collaboration of the chemist and engineer.' Incidentally the gas industry is to be congratulated on this tacit abandonment of the old contention that coal-gas was either none the worse for the presence in it of a certain amount of sulphur impurity, or, alternatively, if worse, that a minute amount of sulphur dioxide in the

atmosphere of a living room is so rapidly absorbed by the ceiling that its harmful effects are nullified.

As the outcome largely of the work of the Joint Committee appointed in 1907 by the Institution of Gas Engineers and the University of Leeds, of which I was a member, to investigate gas-fire problems, the manufacturers of these appliances have paid much more attention than formerly to the scientific aspects of construction so far as to ensure the best combination of radiant and ventilating effects, and nearly all the larger firms have now their scientific staffs busily employed in making further advances. Prominent among the pioneers in scientific gas fire construction has been Mr. H. James Yates, who will to-morrow enlighten you as to some of the most recent improvements. I can, however, from personal knowledge, testify to the enterprise shown by most of the leading manufacturers, and that their combined efforts have resulted in a very efficient and perfectly hygienic domestic gas-fire. A Committee appointed by the Institution of Gas Engineers, upon which scientific men are largely represented, is now considering the adoption of a standard method of testing the radiant efficiencies of gas-fires, so that no one can say that the gas industry is not making every effort to put its affairs upon a thoroughly scientific basis.

Passing on to the metallurgical and allied industries, who, of course, are large consumers of fuel, there is much here to be done in improving the construction and operation of furnaces in order to check the waste of fuel, but of these details there is no time to treat, and one instance of the possibilities of very large economies as the result of scientific control must suffice. It is, perhaps, common knowledge that the most economical arrangement of plant for the manufacture of iron and steel is one in which the by-product coke-ovens, blast-furnaces, steel-furnaces, and rolling-mills are brought together on one site and under one organising direction, so that the surplus gases from the coke-ovens and blast-furnaces may be utilised to the fullest extent. My relative, Mr. T. C. Hutchinson, of the Skinningrove Iron Co., who has devoted many years of anxious thought and practical study to this important problem, ventured some few years ago to predict that with the most approved type and arrangement of plant working under strict scientific control by competent chemists it would soon be possible to make finished steel rails or girders from Cleveland ironstone with no further consumption of coal than is charged into the by-product coke-ovens for the production of the coke required for the blast-furnace, and all subsequent experience at Skinningrove has fully demonstrated that his prophecy can be fulfilled in everyday practice. Of course, it means a constant watchful control by a well-paid and competent scientific staff under efficient leadership, and in Mr E. Bury, an old Owens College student, trained in an atmosphere of 'gas and combustion,' we have found the very man for the work.

It is, perhaps, unnecessary, even had time permitted, for me to multiply instances of possible economies in other important directions, such, for instance, as power-production and the heating of domestic apartments. There is probably no direction in which equally good results would not accrue with proper scientific application and control as those already cited as having been reached or realisable in the direction of carbonisation, or in the iron and steel industry. To-morrow we are to discuss the important subject of Smoke Prevention, in which many Manchester public men are showing an active interest, so that there will be further opportunity of referring to the matter again.

But may I, in conclusion, appeal in all seriousness to chemists and scientific men generally to take up this important matter effectively as a public duty at this crisis in the country's affairs? I would suggest that the Government be memorialised with a view to the establishment of a central organisation for the supervision of fuel-consumption and the utilisation of coal somewhat on the lines of the existing alkali works inspection which has been so beneficial to chemical industry. And in connection with such an organisation there might be undertaken a much-needed systematic chemical survey of British coal-fields, as well as experimental trial of new inventions for fuel economies. There would certainly be no lack of important work of such a properly organised Department of the State, and there can be no doubt at all that the results of its activities would be, not only a very large direct saving in our colossal annual coal-bill, but also a purer atmosphere and healthier conditions generally in all our large industrial areas.

The following Papers and Reports were then read :—

1. *Description and Exhibition of Diagrams used by Dalton in illustrating his Atomic Theory.* By Dr. H. F. Coward *and* Professor A. Harden.

2. *Preliminary Observations on the Nitrile of Vinylacetic Acid.* By Professor Paul Henry, *University of Louvain.*

Several methods have been tried to prepare the substance $CH_2=CH—CH_2—CN$. One might mention the action of moist KCN on allyl iodide, which gives, by a molecular transformation, the nitrile of crotonic acid $CH_3—CH=CH—CN$, and also the action of solid KOH on the nitrile of chlorbutyric acid $CH_2Cl—CH_2—CH_2—CN$, which, however, yields a trimethylene derivative

$$\begin{matrix} CH_2 \\ CH_2 \end{matrix}\!\!>\!CH—CN.$$

It is believed that the nitrile of vinylacetic acid has been prepared by heating for several hours at a temperature of about 120° C a mixture of C_3H_5I and anhydrous $Cu_2(CN)_2$, when a product is obtained which boils at 118° C. and has no smell of an isonitrile derivative.

In order to identify the substance thus obtained, the oxidising action of a cold neutral solution of $KMnO_4$ was first tried. Malonic acid, which should be the characteristic oxidation product of this nitrile, was not definitely obtained, probably because oxidation had proceeded too far.

The action of organo-magnesium compounds to give acetones ($CH_2=CH—CH_2—CO—R$) was also unsuccessful, for the substances $BrMgC_2H_5$ and $BrMgC_6H_5$ only yielded resinous bodies. The action of ozone was next examined. The ozonide of crotonic nitrile when treated with water gave acetaldehyde, but the syrupy ozonide obtained from vinylacetic nitrile was found on analysis to possess the composition anticipated, and when treated with water yielded no acetaldehyde. Its decomposition products have been examined.

3. *Experimental Demonstration of a new Cadmium-Vapour Arc-Lamp.* By Dr. H. J. S. Sand.

The cadmium-vapour arc-lamp exhibited, the use of which is recommended for polarimetric and other purposes, is comparable in general principle with the well-known mercury-vapour lamp. The lamp is constructed of quartz-glass, and the cadmium is freed from oxide and dissolved gas by a process of filtration while at the pump. It is hindered from adhering to the glass by the presence of a small amount of a loose powder (zirconia) in the lamp. The metal is melted by external heating before starting, and maintains itself in the molten condition by the heat of the current. Once started the lamp may be kept burning for an indefinite time.

4. *Joint Meeting with Section A.—Discussion on Radio-active Elements and the Periodic Law.*

5. *Report on Hydroaromatic Substances.*—See Reports, p. 79.

6. *Report on Transformation of Aromatic Nitroamines.* See Reports, p. 82.

7. *Report on Dynamic Isomerism.*—See Reports, p. 81.

8. *Report on Plant Enzymes.*—See Reports, p. 85.

9. *Report on Crystalline Form and Molecular Structure.* See Reports, p. 85.

10. *Report on Natural Plant Products of Victoria.*—See Reports, p. 86.

11. *Report on Influence of Weather Conditions on the Amount of Nitrogen Acids in Rainfall and the Atmosphere.*—See Reports, p. 87.

12. *Report on Non-aromatic Diazonium Salts.*—See Reports, p. 95.

13. *Report on Botanical and Chemical Characters of the Eucalypts.* See Reports, p. 97.

14. *Papers on Flame and Combustion, with Experimental Illustration:*

(*a*) *The Explosion of Gases. By* Professor H. B. Dixon, *F.R.S.*

(*b*) *The Dilution Limits of Inflammability of Mixed Inflammable Gases with Air. By* Dr. H. F. Coward.

(*c*) *Gaseous Combustion at High Pressures. By* Professor W. A. Bone, *F.R.S.*

THURSDAY, SEPTEMBER 9.

The following Discussion took place :—

Discussion upon Smoke Abatement and Air Pollution.

(Ordered by the General Committee to be printed *in extenso*. Edited by Professor W. A. Bone, F.R.S., President of the Section.)

(1) *The Work of the Manchester Air Pollution Advisory Board* [1]

Mr. E. D Simon (Manchester).—The discussion was opened by Mr E. D Simon, Chairman of the Air Pollution Board appointed by the Manchester Corporation in 1912, with the object of diminishing atmospheric pollution by smoke by means of propaganda and research instead of the older method of prosecution. It had been estimated that the measurable damage done in Manchester and Salford by smoke amounts to nearly 1,000,000*l.* per annum, in addition to the immeasurable evil effects of smoke and fog upon public health. Research had mainly been directed towards (1) a more correct ascertainment of the damage done by smoke, and (2) means for reducing both domestic and factory smoke, including all the general problems of smokeless combustion and the electrical deposition of soot and dust. As regards factory smoke, the chief problems are the design of mechanical stokers and the supply of air at the correct point to ensure smokeless combustion, and they can only be solved by large-scale experiments carried out either by, or in conjunction with, manufacturers. However, inasmuch as efficiency and smokelessness usually go

[1] See *Report of the Sanitary Committee of the City of Manchester on the subject of Air Pollution*, April 1915.

together, it is probable that the steady application of pressure by public authorities will in time have its effect in a large reduction of factory smoke.

The most hopeful field for laboratory research lies in the reduction of domestic smoke by improvements in coal and coke fires, gas-fires, and by developing the use of semi-coked coal.

The Manchester Air Pollution Board, with an annual grant of about 450*l.* available for its work, has undertaken two lines of research. In the first place, it was decided to co-operate in the national investigation by measuring the deposition of soot, and also the cutting off of sunlight at ten different stations in or near Manchester; and, secondly, a room has been fitted up at the School of Technology for the purpose of carrying out tests on various kinds of domestic heating appliances, with a view to giving independent and authoritative advice to consumers on the best types of such appliances. It is hoped that similar Research Committees will be appointed by other municipalities, and that the British Association will appoint a Committee to co-ordinate the work of such local Committees.

Professor W. W. HALDANE GEE (of the Manchester School of Technology) reviewed the efforts made in Manchester since 1842 to mitigate the smoke nuisance, and described some of the instruments and experimental methods used in the recent work of the Air Pollution Advisory Board (*vide* Report, *loc cit.*), and the development of the electrical means of causing deposition of dust and soot.[2]

Professor E KNECHT (of the Manchester School of Technology) described the results of investigations on the composition of Manchester soot and the various products obtainable therefrom.

(ii.) *The Work of the Sheffield Health Committee.*

Professor WYNNE (Sheffield University) called attention to the results obtained from an investigation of rain-water collected in standard soot-gauges exposed at four sites in the Sheffield City area during the period July 1, 1914, to June 30, 1915. The investigation, which had been promoted by the Health Committee of the City of Sheffield, and carried out in conjunction with the University, showed that if an opinion as to the contribution of house-fires to pollution of the atmosphere may be based on the proportions of tar and of ammonia collected by the rain (these arising from imperfect combustion of fuel in fire-grates), no material difference could be traced between the values for the summer and the winter six months The data obtained for the Attercliffe site, in the east end of the city, where the armament works are situated, gave values which were roughly about twice as great as those for the other sites, respectively N N W., W., and S of the centre of the city, and attention was directed to the remarkable approach to uniformity in the results obtained from these three sites, which seemed to be independent of the direction of the prevailing wind as recorded each month.

Professor Wynne urged the necessity of creating public opinion on the subject of atmospheric pollution, and supported warmly the suggestion that the British Association should take up the question through a Committee on which various interests were represented, as had been done by the Sanitary Committee of the City of Manchester.

(iii.) *Damage to Vegetation caused by Atmospheric Pollution by Smoke.*

Mr. A. G. RUSTON (Leeds University), in describing the results of investigations recently carried out in and near the City of Leeds, pointed out that the damage caused by coal-smoke to vegetation is due partly to the smoke-cloud reducing the amount of available sunlight, at times by as much as 54 per cent. The black deposit upon the leaves still further hinders the sunlight from getting into contact with the green colouring-matter of the leaf, while the acids present in the smoke damage the structure of the leaf and hasten its fall. Damage is also done to the roots of plants growing in smoke infected areas, possessing few root-hairs or fibrous roots. Moreover, the acid rain falling on the soil limits the activity of the bacteria in the soil, for unfortunately the most useful nitrifying organisms are the most susceptible to acid influences. It has

[2] *Proc. Amer. Instit. of Electrical Engineers*, April 1915.

recently been found that enzymes or ferments which are mainly responsible for the chemical changes taking place in the plant are inhibited by smoke pollution. This causes a distinct cutting down of the intensity of colour in our plants; it also handicaps plants from forming any reserves either in the form of bulbs or seed, and considerably reduces the germination capacity and energy of seeds, thus generally lowering the vitality of plants and preventing them from putting up a fight against adverse conditions.

Professor FERNAND RANWEZ (University of Louvain).—Very many works and factories emit smoke so abundantly as to cause harm to vegetation. Some of them also emit gases which are noxious to plants, and so blight the neighbouring country.

When the fumes are very pronounced the destructive effects are clearly seen, as, for example, near those works which pour out large quantities of sulphur dioxide. In the immediate neighbourhood of such works the plants exposed to the frequent action of the gas have their leaves scorched, while trees lose their leaves and show many dead branches, the action of the gas gradually killing them entirely.

Though these are the most acute symptoms, there are many others far less pronounced, every intermediate condition being observable between plants which exhibit only a slightly checked development and those which die from evident poisoning. Factory smoke and the damage it produces raise frequent complaints from neighbouring landowners and farmers who are, or believe themselves to be, injured, and consequently the courts and experts have to decide the following questions: (1) Has the land of such a person suffered damage, and if so, to what extent? (2) Is the damage wholly or in part the result of the smoke from the factories complained of? The solution of these questions necessitates a comparative study of the general conditions of cultivation and an examination of the actual smoke deposits both on the damaged lands near the works which emit the noxious vapours and districts various distances away.

If perhaps the scorched leaves exhibit some characteristic aspect, there may exist some cause other than mere smoke capable of producing such damage.

The damage is often limited to diminished growth and spread of vegetation, or to a slow withering, and many causes besides smoke produce these effects, such, for example, as faulty cultivation and sour or poor soil.

Vapours often leave their imprint, as, for example, sulphur dioxide (one of the commonest destructive agents), which can be recognised in plants in the form of sulphate. But plants usually contain sulphates in very varying proportion even without the direct action of the gas, so it follows that the discovery of more or less characteristic forms of damage, the observation of the diminution of the spread and growth of plants, or their destruction, the presence of an increased quantity of sulphates or other compounds which could have arisen from vapours do not sufficiently prove the destructive effects of gas when they are considered by themselves alone without all contingent circumstances. The observations only yield proof when they are contrasted with similar ones taken with due care on plants of neighbouring districts. To make such comparative experiments one must describe round the offending factory a series of concentric circles of ever-increasing radius, and then see (1) whether in the more distant regions the vegetation presents normal features, (2) whether it exhibits abnormalities on approach to the factory, and (3) whether such abnormal features become proportionately more marked as the plants become more exposed to the action of the gas.

In all such observations account must be taken of the general cultural conditions of the compared areas. Mere distance from the point of origin is not, however, the only factor on which the noxious action of such vapours depends, for many other factors come into play, such as the prevalence of wind, humidity of the atmosphere, &c.

(iv.) *Improvements in Domestic Fire-Grates.*

Mr. A. VERNON HARCOURT described a type of domestic grate, which he had designed and had in use in his own residence during many years, for burning coal or coke, the extended use of the latter of which as a household fuel would, in his opinion, be a most advantageous means of solving the domestic-

smoke nuisance in all the large centres of population. The grate, which is designed to yield as much radiant heat as possible from the fuel, supports an upright wall of coke, 4 to 4½ inches from back to front, and varying in width from 8 to 24 inches, according to the size of the room to be heated. The grate consists of a series of slender horizontal bars in front and a firebrick slab underneath and at the back. There are ten such bars, each successive pair being two inches apart, so that the height of the grate from the base to the top is 25 inches. It is filled to the top with coke, and on this is laid paper and wood, or other fire-lighter, and a layer of coke with a few pieces of coal reaching nearly to the throat of the chimney. The fire burns from the top downwards.

The grate is charged each morning with an amount of fuel sufficient to last the whole of the day, and, the fuel having been lighted at the top, no replenishment is needed during the day.[3] In the speaker's opinion the essential features of a good grate are :—

(1) The face of the fire should be vertical, so that the chief radiation shall be horizontal and not directed towards the chimney and the ceiling.
(2) The bars should be as slender as is compatible with sufficient strength, and be fixed as wide apart as will suffice to prevent more than an occasional ember falling out;
(3) The fire should be narrow from back to front, for glowing embers which cannot be seen through the front do not radiate heat into the room;
(4) Air should pass in through bars in front, not through bars beneath; for the most vivid combustion occurs where the air and fuel meet;
(5) All the fuel needed during the day should be put in at once at the beginning, and it should be lighted at the top and burnt downwards;
(6) It is well to have two iron plates to divide the fuel into sections for checking the fire, and either plates or doors, closing in front of the upper bars, to draw the fire up when necessary.

(v.) *Recent Improvements in Gas-Fires.*

Mr H. James Yates (Birmingham), who had contributed a paper on 'Recent Improvements in Gas-Fire Science' to the discussion upon 'Fuel Economy' (Section B) at the Birmingham Meeting of the Association in 1913,[4] gave the following account of his more recent investigations in the direction of further improvements in the ventilating effect of gas-fires, which had culminated in a notable advance in this important respect :—

Originally the gas-fire was as nearly as possible an imitation of the coal-fire. It consisted of Bunsen burners so arranged that their flames should play on some incombustible material, so as to bring it to a red heat or something approaching this state. It lost much heat up the chimney, and it gave very little radiant heat; the cost of the gas used was out of all proportion to the amount of heat obtained; also, the fire was apt to smell, owing to the incomplete combustion of the gas. Gradually it was recognised that if the gas-fire was to be made practically efficient on a commercial scale, its economic and hygienic aspects must be studied. At first the economic aspect was almost exclusively dealt with, effort being made to extract more heat from the waste products before their escape by the chimney, and the heat thus extracted being returned to the apartment as heated air. In other words, these early efforts in gas-fire economy aimed at concentrating on convected heat. There was undoubted economy effected, but unfortunately it was accompanied by a bad physiological effect. The convection currents were so hot that the percentage saturation of the air of the apartment was lowered, with the result that moisture was abstracted from the skin and mucous membranes of the occupants, and they suffered unpleasant sensations of dryness, prickling of the skin, and so on. Further, owing to the air of the room being hotter than the walls (because of the heat being mainly transferred to the latter by the medium of the air), persons sitting near these, while feeling discomfort owing to the overheated air,

[3] For details and photographs see *Journal of the Royal Society of Arts*, vol. lxiii, 1915, pp. 570-581.
[4] *B.A. Reports*, 1913, Birmingham, p. 435 (7).

might yet experience chilling sensations owing to the radiation from their bodies to the colder walls.

As a result of these drawbacks, gas-fire heating fell into bad repute, and the position became one only to be retrieved by strenuous research and effort. In this fresh effort the vital importance of the hygienic aspect was at last fully recognised; concentration was made on radiant heat, but care was taken to avoid straining after this, either to an excessive extent or in the direction of over-intensity. The bad results of high-temperature convection being recognised, special convection contrivances were dropped; but the absolute necessity for retaining a certain amount of low-temperature convected heat to supplement the radiant heat was not lost sight of, and express provision for this was made; some progress was also made in improved ventilation.

As regards the question of ventilation, we in this country have always been accustomed to the open fire-grate in our houses, and, generally speaking, we depend very largely on the chimney for the removal of air and the ventilation of the room. This method is by no means ideal; for one thing, the removal of air by the coal-fire *via* the chimney is not infrequently so great that the occupants of the room find themselves inconvenienced by the excessive draught near the door. Inasmuch as the majority of rooms in our houses are ventilated by the fire-place, it is necessary, when a gas-fire is installed, that means be devised to ensure its fulfilling this function to the best advantage. This was far from being the case with the gas-fire heated room of even a very few years ago; the fire was placed in front of the coal-grate, very often with a sheet of iron behind it, thus partly or wholly blocking up the entrance to the chimney, except for the flue outlet of the gas-fire itself. And, in many cases, this flue outlet was of very small dimensions; the amount of air it withdrew from the room was quite insufficient for adequate ventilation In some gas-fires the flue vent and canopy were so designed and proportioned as to draw a large volume of air up the flue, but while in this way quite good ventilation was produced—exceeding anything previously reached in gas fire practice—yet even with such improved fires, free as they were from so many of the objectionable features of the old high-temperature convecting gas-fires, the comfort resulting from the ample air-change effected by the coal fire was not realised. Though the working of the gas-fire itself afforded entire comfort in a room, yet, if it were kept going all day, it was noticeable that the atmosphere was not so pleasant as the day wore on, and in the evening, when the number of the occupants increased, and particularly if gas were used for lighting, the stuffiness became considerable and the gas-fire was blamed. It was indeed the gas-fire that was to blame, but this had nothing to do with its own working as a fire, but was entirely due to the indirect effect on the atmosphere of the partial blocking up of the chimney and the consequent restriction of the ventilation

I recognised that unless this single disadvantage under which the gas-fire still laboured, as compared with the coal-fire, could be removed, the use of gas-fires, extensive though it already was, was bound to remain permanently confined to those householders who adopted it purely as a matter of labour-saving or convenience, instead of broadening, as it ought, into universal adoption. I, therefore, set about endeavouring to produce a fire which should give an ample and controllable ventilation of the room. This major problem was complicated by several other conditions which, though minor in comparison, were yet of such importance that they had to be regarded as indispensable. Great practical difficulties were experienced as regards these minor conditions, not so much in attaining them individually as in the complicated task of reconciling them with each other in the one apparatus. By continued effort, however, the objects in view were eventually all achieved. The fire thus produced, in addition to its embodying the various points of design and construction called for by modern practice, has the further feature, distinctive to itself, of embracing a special contrivance, simple in appearance, but for long most baffling in the course of its evolution, by which, in injector fashion, a very large amount of air is removed from the room. Briefly described, this contrivance provides two outlets to the chimney. The conformation of these and of the adjacent parts is so proportioned, as the result of much experimental work, that by the

under outlet the entire combustion-products are carried off, while by the upper or ventilating outlet a large volume of 'ventilating' air is removed, and volume being controllable by a ventilation regulator.

Mr. Yates then proceeded to describe the results of comparative tests, which proved that the new 'ventilating' gas-fire actually removes at least twice as much air from the room as the previous best types of gas-fires for the same gas-consumption and radiant efficiency, and approaches the ventilating capacity of an ordinary coal-fire as closely as is necessary for the maintenance of a perfectly fresh atmosphere in the apartment heated. Moreover, the tests had proved that this ventilating effect draws air up the flue from all parts of the room, and is at least equal, if not superior, in this respect to that of an ordinary coal-fire. Indeed, having regard to this latest improvement combined with the previous great advances made in the radiant efficiencies and the combustion generally of gas fires, the author is emphatically of the opinion that in every respect they are now more than equal to the best type of coal-fire.

(vi.) *Other Aspects of the Smoke Question.*

Mr. ALFRED HUTCHINSON, of the Skinningrove Iron Co., Ltd (Cleveland District), said that in the manufacture of iron and steel it had been found possible, by the use of by-product coke ovens and of gas-engines generating electric current for driving electrically driven rolling mills, to obtain, from the waste gases from the coke ovens and blast-furnace plant, sufficient spare gas not only to heat up steel ingots in soaking pits, but also to roll them down to finished sections without using any extra fuel beyond the said surplus gases. In addition to this, the valuable by-products could be recovered from the coal charged into the coking-ovens.

Mr. D. BROWNLIE (Manchester) wished to point out that it does not necessarily follow that a smokeless chimney means an efficient boiler plant. For example, the average working thermal efficiency of the boiler plants in this country is probably about 60 per cent. with more or less smoke. If an enormous excess of air is allowed to go through the fires, the smoke can be stopped, but with considerable reduction in thermal efficiency. Under ideal conditions a boiler plant can be running at an efficiency of 85 per cent., with 14 per cent. of CO_2 in the chimney gases, and no smoke. A very slight reduction in the air supply in such a case would give smoke and a reduced efficiency, but this 'smoky' plant might still be much more efficient than the average plant. As a result of many years' experience in fuel economy and smoke prevention, he had arrived at the conclusion that there is no relation between the 'smokiness' of a coal and the percentage of 'volatile matter' which it contains. In every case, however, smoke can be prevented by the application of scientific methods.

Mr. WALTER F. REID (London) advocated the widening of the scope of any Committee that might be formed, so as to include at least 50 per cent. of members who were themselves connected with industries that produce smoke.

The Coal Smoke Abatement Society of London had many members of Council who were connected with industries that in the past had been noxious. The efforts of that Society extending over many years had succeeded in improving the London atmosphere. The London fogs were less numerous and less injurious than formerly.

It was useless to recommend coal-gas for domestic heating unless it could be supplied much more cheaply than at present; the cost at present considerably exceeded that of coal, especially for small dwellings.

Mr. ARNOLD LUPTON (London), speaking of the financial losses sustained by the inhabitants of our industrial towns and cities by reason of their smoke-polluted atmosphere, said that, whilst living near the University of Leeds, he has estimated that the cost to him in damage to furniture and clothing caused by smoke was equal to an annual rate of no less than six shillings in the pound on his rental, and he was satisfied that the shopkeepers suffered an equally serious loss; he thought the smoke nuisance might be removed at the cost of a rate of about one shilling in the pound.

Mr. JOHN W. GRAHAM (Manchester), Chairman of the Smoke Abatement League of Great Britain, cordially supported the proposal for the appointment of

a Committee, which would co-ordinate and give authority to the researches undertaken in various localities, of which they had heard so much during the discussion. No better work for the nation could be undertaken by the British Association than this, and it would certainly grow in importance from year to year.

Mr. ARTHUR BENNETT (Warrington) said that, much as he approved of persuasion as a means of solving the smoke problem, he felt that they ought not to lose sight of compulsion, for he was afraid that there were many manufacturers (a minority, he hoped) who would not make any serious attempt to abate their smoke until they were compelled to do so. Persuasion and education were all very well up to a point, but behind the velvet glove they wanted the iron hand; and, in his opinion, the true solution of the question would be to transfer the administration of the Smoke Acts from the municipalities and the magistrates to the Local Government Board.

The President of the Section (Professor BONE), referring to the desirability of an extended use of coal-gas as a domestic fuel, and for small-scale industrial operations, severely criticised the policy adopted by many municipal gas undertakings, including that of Manchester, of taxing the gas-consumer by making the gas-works pay large sums annually in relief of rates. He understood that the Manchester Corporation taxed its gas-consumers to the tune of 50,000*l.* per annum. A municipal gas-supply should be sold at cost price, after allowing, of course, a reasonable sum for repairs and depreciation of plant as well as interest and redemption in respect of capital outlay. To extract a greater profit by an enhanced price of gas not only penalises unfairly the gas-consumer, thus discouraging the use of gas for domestic purposes, but involves also the payment of income-tax at a high rate on the said 'profits,' thus diverting money quite unnecessarily from the pockets of the local gas-consumers to the Imperial Treasury.

He was decidedly of opinion that the time was both ripe and opportune for a crusade on the question of fuel economy and smoke abatement as a means of national saving in the trying years to come, and he hoped that the Association would lead the way by appointing a strong Committee of representative men to consider the whole question in its national aspects

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The following Paper was then read :—

Experimental Demonstration of Liquid Crystals
By Professor W. J. POPE, *F.R.S.*

FRIDAY, SEPTEMBER 10

The following Papers and Discussion were heard :—

1. *Ruthenium Di-carbonyl* *By* ROBERT MOND, *M.A.*

The author submitted specimens of ruthenium carbonyl and the new ruthenium dicarbonyl, which latter has been obtained by submitting finely divided ruthenium and carbon monoxide to a pressure of 400 atmospheres at a temperature of 300° C. The dicarbonyl was extracted from the powder by solution in alcohol. It is non-volatile, in contra-distinction to the other carbonyls. In common with the other metallic carbonyls it is insoluble in benzene.

2. *The Bone-Callendar-Yates Bolometer.*
By Professor W. A. BONE, *F.R.S.*

3. *Discussion on Homogeneous Catalysis.*

Opened by Prof. W. C. McC. Lewis (*University of Liverpool*).

[Ordered by the General Committee to be printed *in extenso*.]

Prof. Lewis.—In a reaction between two different molecules A and B the usual kinetic method of representing the rate at which this can take place as being proportional to the product of the concentrations of A and B rests, as is well known, simply on the probability of the A and B molecules coming into contact with one another. It has long been recognised, however, that the reactivity depends on other factors as well. Thus, if it were simply a question of probability of collision, one might expect the velocity to be independent of the specific nature of the reaction, being simply determined by the temperature, the mean free path, and the speed of the molecules. Owing, however, to the highly specific nature of the reaction-rate as well as the remarkable effect brought about by a change in temperature, a considerable number of hypotheses generally based upon the formation of intermediate substances have been suggested to account for the mechanism of a given process. There can be no doubt that several of these suggestions are of fundamental importance as regards the molecular mechanism involved. They mainly restrict themselves, however, to material molecular changes and do not attempt to attack the problem of the cause of such changes. In other words, whilst postulating a molecular mechanism which takes account more or less of experimental facts, they give us little or no information respecting the nature, magnitude, and source of the energy exchange, which must accompany or rather precede molecular change. In the same connection we have the whole question of the relation of concentration to active mass which has been studied more particularly in America and which has shown fairly conclusively that concentration *per se* is not an accurate measure of activity except in the limit.

Of the few attempts made to deal with the subject of the rate of a reaction from the standpoint of energy exchange as a necessary accompaniment of molecular change perhaps the simplest and most direct is that of Marcelin as modified by Rice. Marcelin's idea is that a molecule in the mean or average state as regards internal energy characteristic of the system under the given conditions is not capable of reacting in a chemical sense, and that it only becomes reactive when its internal energy rises to or beyond a certain critical value. The energy difference between the mean state and the critical may be conveniently termed the 'critical increment.' Marcelin makes no assumptions as to the mechanism whereby this change in energy content may take place. His view has, therefore, the advantage of generality in not being restricted to any particular type of molecule, atom, or ion. On the basis of the idea of the critical increment it has been shown by Marcelin, and more completely by Rice from the standpoint of statistical mechanics, that the effect of temperature on the velocity constant is given by the expression

$$\frac{d \log k}{d\mathrm{T}} = \frac{\mathrm{E}}{\mathrm{RT}^2},$$

where E is an energy term approximately identical with the critical increment reckoned per gram molecule. This equation is obviously of the Arrhenius type, which has been shown by experiment to be applicable to a large number of reactions of very dissimilar chemical kind. In view of the fact that the Marcelin-Rice equation is in good agreement with experiment, one is prompted to inquire somewhat further into the physical mechanism which underlies the concept of critical energy and critical increment. Two distinct questions arise: first, what is the nature of the energy which is communicated to the molecule, thereby raising its energy content from the mean to the critical state? and, secondly, what internal changes occur in the molecule during this absorption of energy? The second question is obviously the more complicated of the two, involving, as it does, a knowledge of the structure of the molecule. It is not proposed to attempt to deal with this question. The first, however, regarding the form of the energy which is communicated to the molecule appears to be somewhat simpler. The writer would venture to suggest that the energy thus supplied exists in the form of infra-red thermal radiation which is necessarily present throughout the system in virtue of its temperature.

The idea that infra-red radiation may cause chemical reaction is not new. It seems to have been first suggested by Trautz in 1906, mainly from analogy with

photochemical or short-wave reactions. Later Krüger, in 1911, has suggested that infra-red radiation is the cause of such effects as the solubility of a substance in a solvent, electrolytic dissociation and solution pressure. The suggestion made by Trautz has, however, not led to any quantitative results in the field of chemical kinetics, due, no doubt, to the fact that at the time the suggestion was made the ideas of Planck had not received the attention they subsequently did after Einstein had shown that they might be applied to the problem of atomic heats. An important step may, however, be taken by introducing the theory of quanta and applying certain of Planck's relations to the problem of thermal reactivity. I propose to show as briefly as possible that this method of treatment leads to a relation identical in form with that of Marcelin for the variation of the velocity constant with temperature, and if then one equates the two expressions, it will be seen that Marcelin's critical increment under the simplest conditions is identical with one quantum of the infra-red radiation of the type which the substance is capable of absorbing. In other words, we arrive at Einstein's law of the photochemical equivalent for this type of radiation. The application of this view to homogeneous catalysis rests on the assumption that the catalyst is the source of the infra-red radiation which the substance absorbs, thereby becoming reactive in the Marcelin sense. It does not preclude the formation of complexes between the catalyst and the reacting substance, and should apply, not only to the effect of added catalyst (such as the effect of acid on esterification, hydrolysis, inversion, &c.), but likewise to the relative catalytic effect of different solvents when alone and when mixed upon one and the same reaction, and may possibly be extended to cases of chemical reactivity in which catalytic effects as such have not hitherto been recognised.

In the first place, in order that any of Planck's relations may be applied, it is essential that the temperature of the radiation and of the material system shall be the same as that of the surroundings—a condition which can be realised approximately by the use of a thermostat of sufficient heat capacity. If chemical reactivity be dependent on thermal radiation it is evident that the factor of greatest significance will be represented by the amount of radiation of the absorbable or useful type (frequency ν) present per unit volume of the system, in other words, the *energy density* which is usually denoted by the symbol U_ν. For the sake of simplicity, let us consider a monomolecular reaction whose rate according to the ordinary mass action principle may be expressed

$$\frac{dx}{dt} \propto (a - x).$$

If further a catalyst be present, then, in the simplest case in which the catalytic effect is simply proportional to the concentration of the catalyst (C_s), we can write the velocity of decomposition

$$\frac{dx}{dt} \propto \alpha\,(a - x)\,C_s.$$

Such an expression has been found to give results in good agreement with experiment, though it obviously gives no information regarding the mechanism of the energy transfer involved, nor does it predict how the velocity will be affected by a change in temperature. It is therefore incomplete, and it is evident that the introduction of some additional factor is required. On the hypothesis that molecular changes are due to the transfer of radiant energy in quanta, the simplest assumption is to regard the energy density as the significant factor. From this standpoint, therefore, the chemical reactivity or active mass of a substance reacting in the presence of a catalyst depends upon the concentration of the substance, the concentration of the catalyst, and upon the radiation density of the useful frequency ν. The previous equation, therefore, takes the form

$$\frac{dx}{dt} = A(a - x) \times C_s \times U_\nu \quad . \quad . \quad . \quad . \quad . \quad (1)$$

As a matter of fact, this mode of representing active mass is not new except in so far as it is applied to *thermal* reactions. Einstein, in deducing the law of the photochemical equivalent, makes three assumptions, of which one is that the rate at which the light sensitive reactant decomposes depends upon the radiation density. Einstein does not consider the case when a catalyst is present, and further has in view a photochemical reaction in the ordinary sense. It may also be pointed out

that Einstein does not take up the question of the temperature coefficient. Further, Krüger, in dealing with the phenomena of solubility, electrolytic dissociation, and solution pressure already alluded to, makes the assumption that the magnitude of these effects depends directly upon the energy density of the infra-red thermal radiation existing in the system.

Again, it is known that radiation density is a well-defined function of temperature, increasing as temperature increases, so that its introduction into the expression representing active mass has at least the advantage over that ordinarily employed in that it leads one to regard reactivity as itself a function of temperature, a conclusion which is borne out by experiment. We have now to substitute for U_ν its value as given by the theory of quanta. This may be written—

$$\text{constant} \times n^3 \times \frac{1}{e^{h\nu/kT} - 1}$$

where the constant contains the frequency term ν, multiplied by a pure number, n stands for the refractive index of the system for this frequency, h is Planck's constant, T abs. temperature, and k the gas constant per molecule = R/N, where N is the number of molecules in one gram molecule.

Now, it has been pointed out by Mr. Lamble and the writer that the significant range of wave-lengths for the present purpose lies in the short infra-red between 1 and 5μ, and this has been supported by some preliminary measurements made in the writer's laboratory by Mr. Callow upon the infra-red absorption spectrum of hydrochloric acid in aqueous solution, which shows a marked band in the region 1.55μ. For this range of wave-length and at ordinary temperatures it may be easily shown that

$$\frac{1}{e^{h\nu/kT} - 1} \text{ simplifies to } e^{-h\nu/kT}.$$

Hence the velocity equation (1) becomes

$$\frac{dx}{dt} = A(a - x) \times C_s \times \text{constant} \times n^3 \times e^{-h\nu/kT}$$
$$= k_0(a - x)C_s n^3 e^{-h\nu/kT} \quad . \quad . \quad . \quad . \quad (2)$$

Since the effect of temperature is now explicitly allowed for in the final term, it is fair to assume that k_0 is practically independent of temperature. k_0, or rather A, which is included in k_0, appears to stand for the proportionality factor involved in the probability of a molecule of the reacting substance meeting a molecule of the catalyst—either added catalyst such as HCl, or in other cases a molecule of the solvent itself—and hence its maximum variation would amount to 2-3 % for 10° rise in temperature. That this is the significance of the constant A becomes more certain when one remembers that the catalytic effect considered is due to the emission of quanta ($h\nu$) from the catalyst particles, which quanta are absorbed by the molecules of the reacting substance, and it is clear that this transfer would take place most easily when the two kinds of molecules were in close juxtaposition, the disturbance of collision being also a very favourable circumstance for the emission of the quantum and its absorption.

It may be pointed out that at constant temperature and constant concentration of catalyst, which latter defines the numerical value of the refractive index n, that equation (2) reduces to the usual mass action expression—

$$dx/dt = k'(a - x).$$

Again, on integrating equation (2) at constant temperature and catalyst concentration we obtain

$$\frac{1}{t} \log \frac{a}{a - x} = k_0 C_s n^3 e^{-h\nu/kT}.$$

But $\frac{1}{t} \log \frac{a}{a - x} = k_{\text{observed}}$ = velocity constant experimentally observed.

Hence
$$k_{\text{observed}} = k_0 C_s n^3 e^{-h\nu/kT} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

We have now to consider the variation of k_{observed} with temperature. As a first approximation we may regard n as constant for not too great changes in tempera-

ture. C_v can, of course, be kept constant and hence we obtain on taking logs and differentiating:—

$$\frac{d \log k_{\text{observed}}}{d\mathrm{T}} = \frac{h\nu}{k\mathrm{T}^2}.$$

But $k = \frac{\mathrm{R}}{\mathrm{N}}$ where R is the gas constant per gram molecule.

Hence
$$\frac{d \log k_{\text{observed}}}{d\mathrm{T}} = \frac{\mathrm{N}h\nu}{\mathrm{RT}^2} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The term $Nh\nu$ is independent of temperature at least for a very wide range and hence equation (4) may be written $\frac{d \log k_{\text{observed}}}{d\mathrm{T}} = \frac{\text{constant}}{\mathrm{RT}^2}$, which is simply the Arrhenius equation, and has been shown to be in very good agreement with experiment. We may also compare equation (4) with that of Marcelin and Rice, namely, $\frac{d \log k_{\text{observed}}}{d\mathrm{T}} = \frac{\mathrm{E}}{\mathrm{RT}^2}$, where E is approximately the critical increment, that is the quantity of energy which one gram molecule must absorb to make it react. Equating the two terms E and $Nh\nu$ it follows that $\mathrm{E}/\mathrm{N} = h\nu$. But E/N denotes the amount of energy which must be added to a single molecule to make it reactive and this by the above relation is just one quantum of the radiation of the absorbable type ν. This is simply a statement of Einstein's law of the photochemical equivalent, and the fact that under certain simplifying assumptions we have obtained this relation along with an expression for the temperature coefficient which is in agreement with the Marcelin-Rice equation and that of Arrhenius may be taken as some evidence for the general correctness of the ideas underlying the deduction.

Of course, one realises that more than one approximation has been made in the above, and, under certain conditions, therefore, one may expect to find discrepancies between experiment and theory. There is not time to enter into any of these in detail. One may summarise the results which have been further obtained:—

(1) Instead of regarding the refractive index n as a constant, it is more correct to allow for its variation with temperature. Making use of the available data it may be shown that the effect of this variation is to slightly diminish the value of $Nh\nu$.

(2) The index n also is a function of the concentration of the catalyst. When the catalyst is a positive one it can be shown that an increase in its concentration diminishes the temperature coefficient When the catalyst is a negative one it can be shown that increase in concentration increases the temperature coefficient. The experiments of Von Halban and others on mixed solvents support this conclusion.

(3) In the case of a reaction which reaches an equilibrium it can be shown that the heat of the reaction is simply the difference of the characteristic vibration frequencies of reactants and resultants multiplied by h. This relation has already been deduced as a rather special case by Haber.

Mr. J. Rice.—In a series of papers in the *Comptes Rendus*, Marcelin has discussed reaction-velocity, by considering that only those molecules react which reach a 'critical' condition, in which they acquire a certain energy considerably in excess of the average energy per molecule of the system. Marcelin's analysis is very general, and his results can be somewhat extended by some limiting assumptions, which define the 'critical' condition a little more closely.

Consider a simple case of dissociation or combination of two molecules; considerable forces hold the molecules together when near to each other, but the law of force must be such that this attraction weakens and changes to repulsion or non-interaction at some 'critical' distance. This implies that the potential energy of the two molecules is a maximum at this 'critical' distance apart.

In the general case, a certain group of molecules enter into reaction to produce a group of different molecules. We can describe, from a mechanical point of view, the course of the reaction by choosing n generalised coordinates $q_1\ q_2\ \ldots\ q_n$ for a molecular group, and stating the changes which occur in $q_1\ q_2\ \ldots\ q_n$, and in the velocity coordinates $\dot{q}_1\ \dot{q}_2\ \ldots\ \dot{q}_n$ during the reaction. We can choose $q_1\ q_2\ \ldots\ q_n$, so that the kinetic energy, E, of a molecular group equals the sum of squares, $\dot{q}^2 + \dot{q}_1^2 + \ldots\ \dot{q}_n^2$. If we assume also that it is possible to choose the coordinates

so that the potential energy, V, of the molecular group depends on one coordinate only (say q_1); then the above assumption as regards the 'critical' state amounts to the hypothesis that for some value c of q_1, V has a maximum value V_c. The total range of values for q_1 are from a to b (say). For values from a to c the molecular group is in one chemical condition; from c to b it is in the other.

For the reaction proceeding in the sense a to b, we can show by statistical analysis that

$$k = \frac{e^{-\alpha V_c}}{2\sqrt{\pi\alpha}\int_a^c e^{-\alpha V} dq}$$

where k is the velocity constant, and $\alpha = \frac{1}{RT}$. From this can be deduced

$$\frac{d \log k}{dT} = \frac{V_c - V_m + \frac{1}{2}RT}{RT^2},$$

where V_m is the mean potential energy of a molecular group between the conditions a and c; so that $V_c - V_m$ is the 'critical' increment of energy necessary for the reaction.

For the reaction proceeding in the sense b to a, we show that

$$\frac{d \log k'}{dT} = \frac{V_c - V'_m + \frac{1}{2}RT}{RT^2},$$

and therefore

$$\frac{d \log K}{dT} = -\frac{V_m - V'_m}{RT^2},$$

where K is the equilibrium constant.

The idea that the forces involved are electromagnetic, and therefore subject to modification due to a change of radiation density produced by the catalyst, leads to the conclusion that a positive catalyst by reducing $V_c - V_m$ increases k, but decreases $\frac{d \log k}{dT}$, and *vice versa* for a negative catalyst, which is in agreement with whatever experimental data exist. It further can be shown that k varies as some power of e^{γ} where γ is the concentration of the catalyst, a result recently put forward by Rosanoff as fitting the data.

Prof. Francis illustrated and described an apparatus for measuring the velocity of the catalysis of nitrosotriacetonamine and allied derivatives by hydroxyl ions, based on determinations of the pressure of the nitrogen evolved. The method serves also as a means for the determination of the concentration of hydroxyl ions. Neutral salts produce curious effects on the velocity constant, the quantitative retardation in the case of chlorides being nearly the same in such catalysis and in the saponification of methyl acetate and the transformation of diaceton-alcohol into aceton by hydroxyl ions. In small concentrations sulphates produce an acceleration instead of a retardation, and again there is an approximate agreement between the magnitudes of these accelerations in all the above mentioned cases.

The order in which the salts effect the velocity constant is the same as that found in the lyotropic series, namely, iodides produce the greatest, and chlorides the least effect.

Dr. N. V. Sidgwick.—It seems to me that while general theoretical conclusions on the subject of catalysis are of undoubted value, our immediate need is for the accumulation of more experimental data. Thus there is the question of the relation between the catalytic influence and the concentration of the catalyst. Prof. Lewis has assumed them to be proportional. This is no doubt sometimes true, but not always. In some reactions the catalytic effect increases more rapidly than the catalyst, in others less rapidly. In others again, as in Tubandt's experiments on the inversion of menthone, the velocity increases very rapidly on addition of a trace of catalyst, but seems to reach a maximum when the amount is still very small. We do not yet know how these differences are related to other properties of the reacting substances. The fundamental question of the form of the equation is still uncertain. It is commonly written

$$K = k \times C^n \text{ catalyst},$$

where K = observed velocity constant, and n is usually = 1. Now the rate of hydration of acid anhydrides in acid solution is independent of the acidity, but in alkaline solution it increases, roughly, in proportion to the hydroxyl ion. If the rate was always proportional to the hydroxyl it would continue to fall as the solution became increasingly acid, since this involves a continuous fall in the concentration of the hydroxyl; but as a fact the velocity remains constant after the concentration of hydroxyl has fallen to 10^{-7}. This suggests that the reaction is taking place in two ways—(1) by interaction with the catalyst and (2) without its co-operation: and that the equation should be written

$$K = a + b \times C_{OH}.$$

Then when C_{OH} falls to a certain value, depending on the relative magnitudes of a and b, the second term will become negligible, and the velocity will be constant: whereas when C_{OH} is large the first term will vanish and the velocity will be proportional to C_{OH}. If this is true in this instance it may be true generally: only a careful examination of such reactions as admit of accurate measurement can decide.

It may be doubted whether there are any chemical reactions which are *not* catalysed. As Van 't Hoff has pointed out, the influence of the solvent on the velocity is the resultant of two factors, one of which is purely catalytic. When a reaction is said not to be catalysed, this really means no more than that the catalytic influences have remained constant under the conditions of the actual experiments.

It follows from Van 't Hoff's theory that in order to determine the real catalytic influence of a solvent, we must refer the amount of change not to the molar concentration of the reacting substance, but to its solubility: if K is the rate of change, and S the solubility, the catalytic power of the solvent is proportional to K × S. This magnitude has been determined by Dimroth[1] for one of his triazol derivatives in various solvents. He finds that while the rate of change and the solubility vary in the ratio of about 100 to 1, the product varies only in the ratio of 3 to 1. He concludes that this value is approximately constant for all solvents. He omits the case of water, but from his data an approximate value for water can be calculated, and is found to be less than 1/10,000 of that for any organic solvent. This seems to dispose of the view that K × S is constant. But, apart from this, it is evident that what the product really represents is the catalytic influence of the solvent. It is certainly remarkable that the value of this should vary so little for so wide a range of organic solvents (including methyl alcohol, chloroform, and nitrobenzene), and even more remarkable that these values should be of quite a different order from that for water. It is very much to be wished that further data could be accumulated on this point.

In view of Prof. Lewis's discussion of the temperature coefficient, I may draw attention to a remarkable fact pointed out by Von Halban.[2] He shows that not only are the temperature coefficients of isomeric changes, and of monomolecular changes in general, abnormally high, but also those of numerous reactions which are only apparently monomolecular: reactions, that is, which are really polymolecular, but appear to be of the first order because all the reacting substances but one are present in large excess, such as the inversion of cane sugar.

The abnormally high temperature coefficients of monomolecular reactions may be explained thus. A rise of temperature will increase the translational velocity of the molecules, and in general also their internal energy. The second of these effects will tend to increase the rate of change, but in polymolecular reactions the first may be expected to diminish it, since the more rapidly moving molecules will remain within reach of one another's attraction for a shorter time. The ordinary positive temperature coefficients must, therefore, be due to the second effect predominating over the first. If we could find a reacting substance whose internal energy was not increased by a rise of temperature, its rate of reaction should fall as the temperature rose. This is only possible for a monatomic gas; and it is remarkable that the only two reactions whose rates, properly considered, are found to be less at higher temperatures, are reactions of monatomic gases; the recombination of the atoms of active nitrogen, and that of gaseous ions; in the latter instance the positive ion is no doubt usually polyatomic, but only one of its atoms really takes part in the change, and the internal energy of this atom cannot be increased by a rise of temperature.

[1] *Ann.*, **377**, 131.
[2] *Z. Phys. Chem.*, **67**, 174, 1909.

On the other hand, a strictly monomolecular reaction does not depend on the collision of molecules. Hence the restraining influence of the increase of velocity vanishes, and the increase of internal energy has its full effect, giving an abnormally high temperature coefficient. The high values obtained for apparently monomolecular reactions may possibly be explained by supposing that when all the reacting molecular species but one are present in large excess, that one will always find itself within reach of a molecule of the other kind whether its velocity is large or small. It may be remarked, however, that with the acid anhydrides, where the reaction is with the solvent, the temperature coefficients are normal. Any general theory of the temperature coefficients should be capable of explaining these facts.

Professor Baly said that during the last few years certain insight had been gained into the phenomena of chemical reaction from absorption spectra observations. For example, it had been shown four years ago that as a first step in a chemical reaction the reacting compound is converted into an intermediate and highly reactive form. It seems that the formation of the intermediate and reactive phase is a perfectly general phenomenon and one that can be recognised as a fundamental step in any chemical reaction whatever. The reactivity of a molecule is a minimum when that molecule exists in the free state and in general before any molecule can enter into any chemical reaction it must be converted into the active form. The conversion of the inactive to the active form is accompanied by an absorption of energy which may be taken up either from a solvent or as light or heat. According to the quantum theory as originally formulated, this energy must be absorbed in quanta defined by $h\nu$ where h is the Planck constant and ν the oscillation frequency of the radiant energy absorbed. Based on this general theory the definition of a catalyst had been put forward, namely, as an agent which tends to convert more of the reacting substances into the reactive phase than would otherwise be formed.

Professor Baly pointed out that Professor Lewis's theory of catalysis and reactivity appeared to be a mathematical presentation of one single case of his own theory, namely, that case in which the energy absorbed by the molecules had a wave-length lying between 1μ and 5μ in the short-wave infra-red region. Whereas his own theory dealt with the possibility of the energy being absorbed at any vibration frequency characteristic of the reacting substance, Professor Lewis only dealt with the special case of short-wave infra-red radiation, and had shown that by the application of the quantum theory to the Marcelin-Rice equation the increment of energy necessary to convert a molecule into the active form given by $y h\nu$ where $y = 1, 2, 3$, &c., and is the oscillation frequency in the short-wave infra-red region. Professor Lewis in this way has extended the Einstein photochemical equivalent law to the infra-red, and it would seem that as a result of the argument used by him a somewhat anomalous conclusion is arrived at. The essential assumption underlying the Marcelin Rice equation is that a critical increment of energy must be given to a molecule in order to bring it into the reactive condition, this increment being independent of the vibration frequency. Professor Lewis stated that this critical increment may be one quantum at the characteristic vibration frequency of the molecule. Now, the smaller the value of the vibration frequency ν, the smaller is the value of the energy quantum $h\nu$, and therefore it follows from his argument that the actual or total amount of energy necessary to bring a molecule into the active form is smaller, the smaller is the value of ν, *i.e.*, the lower the temperature.

On the other hand, the importance of the Marcelin-Rice equation cannot be denied, and it is of considerable interest that recent work on the absorption spectra of organic compounds had experimentally proved the existence of those very active phases of molecules as intermediate stages in chemical reactions such as postulated by Marcelin. Furthermore, in a recent experimental paper on photochemical reactions, Boll has drawn exactly analogous conclusions as regards the existence of intermediate and active phases of the reacting molecules. The formation of the intermediate and active forms can readily be accounted for by assuming the existence of molecular force-fields due to the juxtaposition of the force-fields of the constituent atoms, these atomic force-fields being electro-magnetic and previously postulated by Humphreys to explain the Zeeman effect and the pressure shift of spectrum lines. The general bearing of these force-fields on chemical reactivity need hardly be emphasised in a discussion on catalysis, but the essential fact should be brought into prominence, namely, that before a molecule can react it must first be converted into an active form by the addition of energy, and that this energy can be absorbed at any vibration frequency characteristic of the molecule.

Before dealing with the quantity of energy necessary for the conversion the relation between the characteristic vibration frequencies of a given molecule must be mentioned. It has been found that the characteristic frequencies of any molecule in the visible and ultra-violet region are simple multiples of a fundamental frequency in the short-wave infra-red region. Thus, if ν be the fundamental short-wave infra-red frequency, there can only be free periods of vibration at 2ν, 3ν, 4ν, &c. These free periods of vibration are evidenced by absorption, fluorescence, or phosphorescence band groups as the case may be. In general, in the case of a simple molecule, only one absorption band group in the ultra-violet is shown, that is to say, only one of the possible multiples of the fundamental short-wave infra-red frequency is active. Such a molecule, therefore, can absorb radiant energy of two frequencies only between the wave-length limits 5μ and $0{\cdot}2\mu$, namely, at the fundamental infra-red frequency ν and the ultra-violet frequency ν_1, where $\nu_1 = y\nu$, y being a positive integer. According to the Einstein law, if the molecule undergo a photochemical reaction, the minimum quantity of energy required will be given by $h\nu_1$.

On the other hand, if the energy be absorbed at the lower frequency ν, it would seem that the same total quantity must be taken up in order to bring the molecule to the active condition. That is to say, y quanta must be absorbed at the lower frequency, since $h\nu_1 = yh\nu$. This must be the case if the Marcelin conception hold good that the critical increment of energy necessary to bring the molecule into the reactive state is independent of the vibration frequency.

This modification of Professor Lewis's theory would seem to bring it into harmony with the general results of absorption spectra observations. One further deduction may perhaps be made. Professor Lewis stated that in order to bring a molecule into the reactive phase a whole number of energy quanta must be absorbed in the short-wave infra-red region. The molecule, however, can also absorb energy at a frequency which is a multiple of that infra-red frequency. There does not appear to be any obvious reason why any one multiple should be active more than any other multiple in the ultra-violet. It would seem possible from the foregoing to deduce an explanation. If the total energy necessary were equal to y quanta at the infra-red frequency then the active frequency in the ultra-violet would be y times the infra-red frequency, that is to say, the multiple of the infra-red frequency active in the ultra-violet is defined by the number of infra-red quanta which together amount to the necessary energy increment. There would seem to be no difficulty in advancing a mechanical explanation of the foregoing somewhat analogous to that put forward by Bohr for atomic structure. A development of this would be out of place in this discussion, but the general conception has the merit of bringing Einstein's photochemical law and Marcelin's and Lewis's theories into line with absorption spectra observations.

One of the most interesting features of the phenomena of reactivity and catalysis is the frequent failure of the law of mass action. It is obvious, in those cases where the conversion of the inactive molecules into their active forms is brought about by the action of a solvent, that if the relation between the effective masses of active and inactive phases obey the law of mass action no advantage would be gained by the theory. A quantitative investigation of the relation between the two has shown, however, that the mass action law is not obeyed. In the simplest case, where the molecule is converted into the active form by the action of a solvent, it is clear that if x be the fractional part converted into the active form, x should be independent of the concentration if the law of mass action hold good. Experiment has shown that x is not constant, but that $x = 1 - e^{-\alpha V}$ where V is the volume of the solution and α is a constant depending on the nature of solvent and solute. If A/A_1 be the ratio between the masses of active and inactive molecules, then

$$\log \frac{A_1}{A_1 - A} = \alpha V;$$

in such case the solvent is acting as catalyst, and it would seem that the behaviour of catalysts generally is susceptible of explanation on the above lines.

An interesting point is to be noted in connection with the formula, namely, that when α is very small x remains appreciably constant with changes in V when V is small. In other words, the law of mass action is approximately obeyed in fairly concentrated solutions.

A short general discussion followed.

4. *The Molecular State of Salts in Solution.*

By W. E. S. TURNER *and* J. D. CAUWOOD.

At the 1910 meeting of the Association, one of us demonstrated that the haloid salts of organic ammonium, sulphonium, and oxonium bases were highly associated in a neutral solvent, *e.g.*, chloroform, and evidence was tendered to prove that salts in general are complex molecular substances. Subsequent investigations have brought within the scope of these conclusions metallic salts, whilst the effect of the solvent has also been thoroughly tested. As the salts hitherto employed have been the haloid salts almost entirely, the general conclusions would be greatly strengthened if it could be shown that salts of acids other than the haloids are also associated.

For the purpose of this investigation, therefore, a number of new salts have been prepared, including tetrapropylammonium fluoride, chlorate, bromate, iodate, sulphate, thiocyanate, oxalate, and benzoate. All of them have high molecular weights in chloroform. Thus, the observed molecular weight of the thiocyanate in 4 per cent. solution is nearly seven times the value for the simple formula.

At the same concentration (25 milligramme molecules per 100 c.c. of solvent), the degree of association increases in the order : iodate, oxalate, chloride, bromide, bromate, chlorate, sulphate, iodide, benzoate, nitrate, periodide, thiocyanate, fluoride.

5. *Ionisation in Solvents of Low Dielectric Constant.*

By W. E. S. TURNER.

In extension of previous work on conductivity in solvents of low dielectric constant, Sachanov [1] has found that the conductivity of a mixture of electrolytes exceeds that of the sum of the conductivities of the single electrolytes by an amount which is greater the lower the dielectric constant of the solvent. From his results, he argues that in solvents of the type used the degree of dissociation of one electrolyte is materially increased by a second one added.

This interpretation is capable of test by freezing or boiling-point tests on the solutions. Experiments on solutions in chloroform, one of the solvents used by Sachanov, show that the salts tetrapropylammonium iodide, diethylammonium chloride, triethylammonium bromide, phenylethyl- and phenyldiethylammonium chloride and iodide, so far from causing increased dissociation when dissolved in pairs, have just the reverse effect, producing an increased degree of association. That is to say, Sachanov's interpretation is incorrect, and, whereas in water the molecular conductivity increases as the average size of the electrolyte molecules decreases, in solvents of low dielectric constant the reverse is the case.

This conclusion is in harmony with several phenomena previously pointed out by the writer,[2] and also with the fact that the conductivity in solvents of low dielectric constant increases as the molecular size of the solute increases.

[1] *Zeitsch. physikal. Chem.* 1914, 87, 441.
[2] *Trans. Chem. Soc.* 1911, 99, 880.

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION:—PROFESSOR GRENVILLE A. J. COLE, F.G S., M.R.I.A.

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address:—

IN his Address to this Section at Sydney in 1914, my predecessor, Sir Thomas Holland, dealt with the problem of isostatic balance in the earth's crust, and with the relation of crust-movements to what Ampferer has styled the *Untergrund*. Such broad questions must appeal to all geologists. Without movements of the surface, the ocean-depths would become diminished by infilling from the denuded lands, and the water would spread, by a general transgression, across the shores of worn-down continents. Rivers would become reduced, both in length and volume, and there would be a marked diminution in the salts carried to the sea. Molluscan life would probably profit by the greater extent of warm and shallow waters, while the variety of animal types on a given land-area would decrease before a growing equality of conditions. Volcanic action, so commonly the accompaniment of large displacements, would no longer find definite lines of outbreak, and a number of interesting petrographic types might remain unseen or even undifferentiated in the quiescent cauldrons of the crust. Students of tectonics, physical geography, palæontology, and petrography are thus alike concerned with superficial warping. More than this, the whole life of man, his future as much as his past, is conditioned by the security or insecurity of the land on which he moves. If to-day I venture to touch on some of these large aspects of our science, it will be understood that this is not from any pride of knowledge on my part, or from any special grasp of a 'theory of the earth.' The conclusion that I should prefer to emphasise is that the faithful and minute observations of the geologist, the discussion of detail, the aid that he may draw from the experiments of the chemist and the physicist, and, above all, the frequent conference with others in the field, all tend to an understanding of human surroundings on this strange rotating globe. The globe is still strange to us, because its vast interior is unseen; and we are apt to speculate about the stars, when the behaviour of the ground beneath us concerns us far more nearly

Changes in the relative Proportions of Sea and Land.

The geologist has long been accustomed to regard the crust beneath his feet as subject to changes which are immeasurably slow in comparison with the duration of his personal life. Since the days of Lyell, the processes of reconstruction have seemed to us as mild and lengthy as are the processes of decay. It is true that even the latter processes display vigorous tendencies in the form of landslides and the paroxysmic eruptions of volcanoes, while earthquakes at times are accompanied by visible displacements of the crust, such as that which, at Yakutat Bay, in 1899, raised the sea-coast as much as forty-seven feet.

These somewhat exceptional manifestations come well within our conceptions of uniformity, and many of us have felt with Lyell[1] 'that the energy of the subterranean movements has been always uniform as regards the *whole earth*. The force of earthquakes may for a cycle of years have been invariably confined, as it is now, to large but determinate spaces, and may then have gradually shifted its position, so that another region, which had for ages been at rest, became in its turn the grand theatre of action.'

James Hutton has sometimes been charged with catastrophic tendencies, in requiring a complete wearing away of the continents, followed by a somewhat sudden restoration of the land-surface. But he was careful to urge[2] that 'the powers of Nature are not to be employed in order to destroy the very object of those powers; we are not to make Nature act in violation to that order which we actually observe.' To him, the object of the earth's existence was the propagation of life, and particularly of man, upon its surface. We must presume that the destructive outpourings of the lava-rifts of Laki in 1783 and the human hecatomb on the quay at Lisbon in 1755 had not appealed to him as breaks in an orderly succession. He admits[3] that 'this world is thus destroyed in one part, but it is renewed in another; and the operations by which this world is thus constantly renewed are as evident to the scientific eye as are those in which it is necessarily destroyed.' Yet the operations that are to 'give birth to future continents,' as well as those that wear down a continent to the level of the sea, are not the result of 'any violent exertion of power, such as is required in order to produce a great event in little time; in nature, we find no deficiency in respect of time, nor any limitation with regard to power.'[4] Far from believing in the complete loss of the former land-surface before upheaval raised the new, Hutton points out that 'the just view is this, that when the former land of the globe had been complete, so as to begin to waste and be impaired by the encroachment of the sea, the present land began to appear above the surface of the ocean. In this manner we suppose a due proportion to be always preserved of land and water upon the surface of the globe, for the purpose of a habitable world, such as this which we possess.' He then observes that the materials brought to light from the bottom of the sea must have been derived from a land-surface still older than that which is decaying simultaneously with the uprise of new continents. Though he speaks of the strata formed at the bottom of the sea as becoming 'violently bended, broken, and removed from their original place,' he refrains from definite assertions as to the details of the process of elevation.[5] Fusion, whereby original rock-structures are lost, subsequent consolidation, and final upheaval by thermal expansion, seemed to Hutton the broad stages of that part of his cycle which is concerned with reconstruction. He certainly speaks[6] of 'the greatest catastrophes which can happen to the earth, that is, in being raised from the bottom of the sea, and elevated to the summits of a continent, and being again sunk from its elevated station to be buried under that mass of water from whence it had originally come.' But the gist of his whole treatise is that the process of degradation is brought about by slowly acting causes, and the 'catastrophe' of elevation is kept well out of the picture, on the ground that we are unable to follow out its successive stages.

Hutton's insistence on the recurring cycle of geological events was of immense value in checking the imagination of those who revelled in the contemplation of

> 'Crags, knolls, and mounds, confusedly hurl'd,
> The fragments of an earlier world.'

Stellar observation and physical chemistry, however, have alike led us to look for evolutionary processes in the globe; and it is well to ask if the conditions prevalent at the present day are necessarily those of previous periods, or have

[1] *Principles of Geology*, vol. i. (1830), p. 64.
[2] *Theory of the Earth* (1795), vol. ii. p. 547.
[3] *Ibid.* p. 562.
[4] *Ibid* (1795), vol. i. p. 182.
[5] *Ibid.* pp. 163, 164, 184, and 121.
[6] *Ibid.* vol. ii. p. 445

even persisted since the surface became suitable for the amatory escapades and internecine enterprises of living organisms.

Few geologists, for instance, will now urge with Hutton that a 'due proportion' has always been preserved between land and water on the surface of the globe, if by those words is meant a proportion such as we now enjoy. We may remark, in passing, that the proportion regarded with complacency by Hutton may have suited the populations and ambitions of the eighteenth century; but recent events have at any rate shown the need for an expansion of the continents.

If we go back to early times, we must consider, with R. A. Daly,[7] the possible grouping of the land against which the Huronian or late pre-Cambrian sediments were formed. The stimulating imagination of this author has proposed a threefold explanation of the absence of calcareous coverings or strengthenings from the organisms of primæval seas. I use the word 'imagination' advisedly, since the power of conceiving what has happened in the past is not necessarily limited by observation of what is now going on around us. The conclusions of Hutton as to the nature of the contact of granite and sediments in Glen Tilt, and those of G. P. Scrope as to the dynamic origin, or at any rate the dynamic intensification, of foliation in crystalline rocks, are triumphs of the imaginative faculty. The geologist who represses his imagination does, perhaps, excellent observational work; but if this repression becomes habitual, others will reap the intellectual harvest of which he has counted out the seeds.

R. A. Daly, then, has imagined, as one of the causes contributing to a 'limeless ocean,' a primitive distribution of land and water very different from that which determines our continental land to-day. His pre-Huronian land-surface is pictured as merely a number of large islands, on which no long and conspicuous rivers could arise. Granitic rocks, moreover, prevailed, and basic materials, capable of supplying calcium in abundance, had not yet become prominent in the surface-layers of the crust.

It may be said that this primitive condition of the distribution of land and water is very unlikely to return. But we have evidence that Hutton's 'due proportion' has been interfered with from time to time. The conversion of the Danish area into islands in the human epoch, and the severance of the British region from continental Europe, are merely pictures in little of what may happen in an unstable crust. The very general spread of the sea over the land-margins in Cenomanian times is attributable to a shallowing of the ocean-floors, and it is difficult to say whether this process has been rhythmic or exceptional in the history of the globe. The Carboniferous period opened with marine conditions over a large part of the northern hemisphere, indicating, not only a continuation of the Devonian seas, but an overflowing of much of the Caledonian land. The same period closes with an extension of the continental edges, and the formation of swampy flats, in which the vegetation of the epoch has been abundantly preserved. Similarly, the sea which deposited the Cretaceous strata, after encroaching alike on South Africa and Scandinavia, withdrew to a considerable extent in Eocene times, and its perpetuation along the Mediterranean belt only calls attention to its subdivision or absence in other areas.

The Foundations of the Earth's Crust.

Hutton, however, remains at present unassailable in one of his most remarkable propositions. He was not troubled by any theory of nebular origins, nor by isogeotherms and their gradual retreat from the surface on which we live. For him, the oldest rocks that we know are sedimentary, and these sediments differed in no respect from those of modern days. This conclusion has perhaps not received the full attention that it deserves. It was based on philosophic reasoning rather than on observation, and its world-wide truth has only recently become appreciated. It now appears certain that we possess no record of a

[7] 'The Limeless Ocean of Pre-Cambrian Time,' *Amer. Journ. Sci.*, vol. xxiii. (1907), p. 113; and more fully in 'First Calcareous Fossils,' *Bull. Geol. Soc. America*, vol. xx. (1909), p. 157.

sedimentary type peculiar to the early stages in the formation of a habitable crust. If such a type existed, it has been lost to us through subsequent metamorphism, amounting to the actual fusion and redistribution of its constituents. The Grenville series of North America, first recognised by Logan, has been studied in considerable detail.[8] Its relation to the Keewatin series of Canada is unknown, but it rests on a floor of granitoid rock, which is intrusive in it, and which belongs to the oldest of various irruptive groups. The Grenville series includes conglomerates, false-bedded quartzites, and a development of limestone that is altogether exceptional for pre-Cambrian times. In Finland,[9] sediments have been traced down to the layer where their original characters vanish in a general 'migmatitic' ground. The Bottnian and the still older Ladogan systems alike provide us with strata in which primary characters have been preserved. Conglomerates and phyllites occur among them, and near Tampere (Tammerfors) the seasonal stratification is as well recorded in a Bottnian shale as it is in the Pleistocene clays made famous in Sweden by De Geer. Vein-gneiss (Ådergneis) underlies these ancient systems, and represents their destruction by the injection of granite from below. It is to be noted that J. J. Sederholm [10] believes that in several places in Finland the 'basement complexes of the typical Archæan sedimentary formations' have been preserved. These, however, may well be also sedimentary, and thus similar in origin to the later complexes above them. Their surfaces must be due to denudation, and their igneous constituents were intruded into rocks which may have been merely a cover worn from still older masses.

If we accept the meteoritic and planetesimal hypotheses of Lockyer and Chamberlin, it is quite possible to argue that the primitive crust was never molten as a whole It may never have lost its fragmental structure, which was original and due to accretion from without. When agents of denudation came to work upon it, a chemical as well as a mechanical sifting of various materials came about. The oldest sediments were less differentiated than their successors; chemical adjustments may then have been made in response to demands from the interior of the globe [11]; and ultimately normal types of sediment—that is, types to which we are now accustomed—began to gather in hollows of the surface. So far, Hutton's position becomes strengthened by the postulation of an unfused planetesimal crust, and the restriction of molten masses and hydrothermal activity to the interior of a consolidating globe.

The doctrines of Laplace, however, led Hutton's immediate successors to see in crystalline schists the products of abnormal sedimentation. In their view, a molten globe became surrounded by a slowly consolidating crust, and highly heated waters, playing upon this, deposited crystalline material on the floors of primordial seas [12] Among other workers on pre-Cambrian rocks, T G Bonney [13] has upheld the view that the conditions under which schists were formed have not been repeated in later geological times This is, of course, true if they are deposits from hot solutions and were laid down at the surface of the earth

R. A Daly [14] has reasoned that we may accept the planetesimal view and yet believe that a molten surface prevailed at some time over the whole globe; and A. Holmes,[15] in a recent and lucid paper, supports these arguments from the

[8] F D. Adams and A E Barlow, 'Geology of Haliburton and Bancroft Areas,' *Geol. Surv. Canada*, Mem. 6 (1910), p. 36.

[9] J. J. Sederholm, 'Ueber eine archaische Sedimentformation im sudwestlichen-Finland,' *Bull. Comm géol Finlande*, No. 6 (1899), p. 215.

[10] *Op. cit.* No. 6, p. 213, and 'Om Granit och Gneis,' *ibid.*, No. 23 (1907), p. 100.

[11] See C. H. L. Schwarz, *Causal Geology* (1910), p. 11.

[12] G. P. Scrope, *Considerations on Volcanos* (1825), p 226.

[13] Presidential Address, *Quart. Journ. Geol. Soc. London*, vol. xlii (1886), *Proceedings*, p. 110. See also T. Sterry Hunt, 'Études sur les Schistes cristallins,' *C.R., Congrès géol. internat.* 1888, p. 65.

[14] *Igneous Rocks and their Origin* (1914), p. 159.

[15] 'Radio-activity and the Earth's Thermal History,' *Geol. Mag.* 1915, p. 105. On the power of radio-active substances to promote rock-fusion see, however, J. P. Iddings, *The Problem of Volcanism* (1914), p. 141.

probabilities of radio-active heating. Yet, so far as we have any record left to us, Hutton remains fundamentally in the right. All modern research shows that the schists and gneisses can be explained by causes now in action. The vast majority of schists were at one time normal sediments; others were tuffs or lavas; but, whether originally sedimentary or igneous, they owe their present characters to widely spread regional metamorphism.

The Undermining and Weakening of the Foundations of the Crust

Is there, then, any reason to depart from Hutton's position as to the recurring cycle of events in the history of continental land? I think it must be admitted that the isostatic balance was far more frequently disturbed in what we may call Lower pre-Cambrian times than it has been in more recent periods. Osmond Fisher [16] has pointed out the possibility of local melting of the substratum of the crust by convection-currents in a liquid layer, and the consequent weakening of the mass above. The differences in composition of various parts of the crust render them, moreover, susceptible to fusion in various degrees, whatever may be the source of the heat by which they are attacked Local fusion must indeed be regarded as an important cause of crustal weakening If we wish to study the nature of the process, it is reasonable to examine regions that have at one time lain deep within the crust Such regions are provided by the broad surfaces of Archæan rocks that were worn down through continental decay before they sank beneath the Cambrian sea

It is well recognised that an ancient continent, resembling in most of its features the present 'Russian platform,' at one time stretched across the northern hemisphere Wherever later deposits have been stripped from its surface, from central Canada to the Urals, and probably far beyond, we find that the older materials of this undulating continental platform consist largely of intrusive igneous rocks These, moreover, have frequently a gneissic structure Again and again, strongly banded gneisses occur, in which granitic material verging on aplite, alternates with sheets of hornblendic or biotitic schist. The biotitic varieties can often be traced back into amphibolites. In places, lumps of these amphibolites are seen, streaked out at their margins, and providing a clear explanation of the dark bands throughout the gneiss.[17] This swallowing up of a mantle of basic material by a very different and highly siliceous magma rising from below is, indeed, seen to be a world-wide feature, wherever we find the lower crust-layers brought up within reach of observation The tuffs and lavas of the Keewatin series have supplied the dark material in Canada, and similar rocks have been worked up into the gneisses of Galway, Stockholm, and Helsinki The frequency of amphibolite in these ancient composite rocks is explained by the fact that this type of rock is the final term of various metamorphic series. While many lumps, for instance, in the gneisses of Donegal are residues of Dalriadian dolerites (epidiorites), others, rich in garnet and green pyroxene, and often containing quartz, are derived from a mixture of sediments in which limestone has been prevalent.[18] During the absorption and disappearance of these masses in the invading granite magma, the

[16] *Physics of the Earth's Crust*, ed 2 (1889), p 77.

[17] Since the historic works of A C Lawson (for example, 'Report on Rainy Lake Region,' *Geol Surv Canada*, Ann Report for 1887, plates v and vi), these features have been traced in many areas Compare W H. Collins, 'Country between Lake Nipigon and Clay Lake, Ontario,' *Geol Surv Canada*, Publication 1059 (1909), p 52; A L Hall, Presidential Address on the Bushveld Complex, *Proc. Geol Soc S Africa*, 1914, p xxii; P. A Wagner on Rhodesian gneisses, *Trans. ibid*, vol. xvii. p 39; and works cited in the next reference

[18] See Michel Lévy, 'Granite de Flamanville,' *Bull carte géol. France*, vol. v. (1893) p. 337; G A J. Cole, 'Metamorphic Rocks in E Tyrone and S. Donegal,' *Trans. R Irish Acad.*, vol. xxxi. (1900), p. 460; O. Trüstedt, 'Die Erzlagerstätten von Pitkäranta,' *Bull Comm géol Finlande*, No 19 (1907), pp 72 and 92; F D. Adams and A E Barlow, *op cit* (1910), pp 25 and 97; F Kretschmer, 'Kalksilikatfelse in der Umgebung von Mährisch-Schönberg,' *Jahrb. k. k. geol. Reichsanstalt*, vol. lviii. (1908), p. 568; &c., &c.

amphibole acquires potassium and breaks down into biotite, and biotite-gneisses result, which may extend over hundreds of square miles.

The details of such an igneous invasion are worthy of careful study, since only in this way can we follow out the progress of sub-crustal fusion. We see the highly metamorphosed material further attacked by the great cauldrons under it, and becoming seamed with intersecting veins. Block after block has been caught, as it were, in the act of foundering into the depths. In the gradual absorption of these blocks, and their penetration by insidious streaks of granite, we see pictured on a few square yards of surface the destruction of a continental floor.

To realise the magnitude of the process, however, hand-specimens and museum-specimens will not suffice. Here, as in all branches of geology, travel is the best of teachers, and the finest illustrations in a Geological Survey memoir will not convey the same impression as one wave-swept island of the Finnish skägard, a glaciated hillside in Donegal, or a dome of the Laurentian peneplane, from which the forest has been burnt away.

I am aware that in this statement of the relations of the Archæan gneisses to the overlying floor I am neglecting the effects attributed to dynamometamorphism. A rise of temperature, leading to molecular readjustment, is usually admitted by those who lay stress on the evidence of pressure, and study in the field along what may be called regional contacts produces the impression that thermal influence is a very potent factor. This is not the place for a review of the position taken by French observers,[19] who have done so much to enlarge our ideas of contact-alteration and intermingling. It is sufficient to remark that such contact-alteration, acting over wide areas, including as it does the advance of permeating liquids, goes far to account for the 'mineralisation' of previously normal sediments, while the injection of which there is such abundant evidence will explain the numerous varieties of composite and banded gneiss. J. Lehmann [20] restricted the term 'gneiss' to foliated igneous rocks in which the parallel structure was due to original flow or subsequent crushing, and denied the existence of a passage from mica-schist to gneiss. He left no place in his classification for the composite rocks that furnish so much information as to the methods of sub-crustal fusion. When such an authority as J. P. Iddings [21] hesitates to accept either the assimilation or the stoping theory as explaining the advance of an igneous magma on a large scale in the crust, I feel that I may not be able to carry all my hearers with me in this part of my argument as to the causes of terrestrial collapse. I can only say that I support certain conclusions, because I can conceive no other reading of the evidence offered in the field. When it is asserted that the earth is not hot enough to allow of the melting of one rock by another, I can only reply that such melting has taken place. The influence of liquids and gases in promoting fusion has been emphasised by Iddings, Judd, and Doelter. Even with this aid, we may not be able to explain the facts, though I think that we have gone a long way towards doing so. In the history of all the sciences, however, observation has run far beyond understanding.

Fortunately the argument that I hope to develop as to the comparative rapidity and possibly catastrophic character of certain crustal changes depends only in part on views that are still under discussion.

The invasion of a 'hard and brittle' [22] crust by an attacking magma was finely described by Lawson in 1888. Lawson pointed out that the Laurentian

[19] Michel Lévy summarised his views, side by side with essays by other authors, in 'Études sur les Schistes cristallins,' *C. R., Congrès géol. internat.* 1888, p. 117. See also P. Termier, 'Les Schistes cristallins des Alpes occidentales,' *C. R., Congrès géol. internat.*, 1903, p. 571. Compare numerous later observers, such as P. S. Richarz, 'Umgebung von Aspang,' *Verhandl. k. k. Reichsanstalt*, 1911, p. 285.

[20] *Op. cit., C.R., Congrès géol. internat.*, 1888, p. 115.

[21] *Igneous Rocks*, vol. i. (1909), p. 282; *The Problem of Volcanism* (1914), p. 200.

[22] A. C. Lawson, *op. cit.* p. 140. See also his revision of the area, *Geol. Surv. Canada*, Memoir 40 (1913).

gneisses gave no evidence of having 'yielded to pressures and earth-stresses.' The folding of the overlying series was prior to the solidification of the gneisses, and occurred [23] 'while the latter were yet in the form of probably a thick, viscid magma upon which floated the slowly shrinking and crumpling strata of the Coutchiching and Keewatin series. . . . Large portions of these rocks have very probably been absorbed by fusion with the magma, for the Laurentian rocks appear to have resulted from the fusion not simply of the floor upon which the Coutchiching and Keewatin rock first rested, whatever such floor may have been, but, also, with it, of portions of those series.'

The intense crumpling of the lower portion of the invaded series is not correlated by Lawson with the approach of the invader The conversion of the lowest Archæan series, the Coutchiching sediments, into crystalline schists is, however, attributed to thermal metamorphism, and to hot vapours streaming from the molten floor.[24] Lawson realised the importance of shattering in allowing a magma to advance into an overlying 'brittle' series, and he is, so far as I know, the first observer to develop in satisfying detail what is now known as the stoping theory of igneous intrusion. J. G. Goodchild [25] soon afterwards described a striking example of rock-destruction by stoping and assimilation in the west of Scotland, where one of the 'newer granites' enters the Moine schists, and J J. Sederholm,[26] in dealing with 'Ádergneis' in Finland, extended Lawson's views in a new field of regional metamorphism.

James Hutton always had in mind the effect of heat in 'softening' lower layers of the crust His consolidation of strata by heat is preceded by a stage of melting. Sederholm, while referring back to Hutton as the pioneer, shows how in the vein-gneiss stage the unmelted sediments exhibit plasticity and become intensely contorted. The softening, in fact, induces flow. There is here no crushing or mylonitisation, but rather a viscid running of constituents, some on the verge of fusion, some, I venture to think, actually fused. Such rapidly repeated and intricate folding in metamorphosed sediments has been described as 'shearing' by some authors. Neither in the field nor in thin sections under the microscope can such a position be sustained. Shearing or attempted shearing may subsequently produce what has been called 'strain-slip cleavage' in the folds; but the folding has an earlier origin, and is very often associated with thermal changes. It is most intense when *lit par lit* injection has set in, and when the whole composite mass has become weak and plastic. The presence of confined water in aiding this plasticity must on no account be overlooked.

It may be well to illustrate this contention by one or two concrete instances from districts not remote from us at the present time. The noble cliffs of Minaun in Achill Island have been worn by the Atlantic from a mass of evenly bedded quartzites of Dalriadian age. These are invaded by veins of a very coarse red granite, the main mass of which lies below the present sea-level.[27] The edges of the strata appear fairly horizontal on the cliff-face; but contortion sets in towards the base, and the hard resisting rock has here [28] 'undergone intense crumpling and overfolding, such as one meets with on a large scale in mountain ranges, and this contorted flow seems entirely due to the yielding that has taken place in the region of heating' The veins have broken in sinuous forms across the folds, just as they do in the intensely contorted vein-gneisses of Finland. They here represent a late episode, occurring

[23] *Op. cit.* on Rainy Lake, p. 131.

[24] Compare P. Termier, 'Schistes cristallins des Alpes occidentales,' *C. R., Congrès géol. internat.*, 1903, p. 585.

[25] 'Note on a Granite Junction in the Ross of Mull,' *Geol. Mag.* 1892, p. 447. Compare T. O. Bosworth on same area, *Quart. Journ. Geol. Soc. London*, vol. lxvi. (1910), p. 376.

[26] 'Ueber eine archäische Sedimentformation im südwestlichen-Finland,' *Bull. Comm. géol. Finlande*, No. 6 (1899), p. 133; and 'Ueber ptygmatische Faltungen,' *Neues Jahrb. für Min.*, Beilage Band 36 (1913), p. 491.

[27] *Proc. Geol. Assoc.*, vol. xxiv. (1913), Plate 17.

[28] G. A. J Cole, 'Illustrations of Composite Gneisses and Amphibolites in N.W. Ireland,' *C. R., Congrès géol. internat.*, Canada (1913), p. 312.

in place at the top of the granite mass and in time at the close of its advance. The large size of the constituent crystals of the granite indicate that the surrounding rock was still maintained at a high temperature.

The features induced in the quartzite resemble those that are due in other cases to regional deformation. It may be urged that they represent some such crumpling during the rise of a laccolitic dome. Though such a dome, in Gilbert's view, implies stretching rather than compression, pressure from one side may thrust the rising beds together and produce local overfolding. On the other hand, the short section exposed in Achill may be part of a synclinal down-sagging. It is difficult, however, in either case to avoid associating this limited field of disturbance with the proximity of the igneous rock, particularly when other cases can be compared with it. South of Foxford, for instance, in the county of Mayo, the granite of Slieve Gamph invades a series of mica-schists and quartzites. Further west, and over a wide area towards Castlebar, this granite has become darkened and gneissose through assimilation of the schists; but here above Kilmore its advance was stayed, and the margin is cut, as usual, by veins that filled the cracks both of the main granite and the metamorphosed sediments. These sediments have become, prior to the shattering, crumpled and overfolded along the contact-region, and the section upon the glaciated slope resembles that of a fluidal rhyolite on a highly magnified scale

The wonderful contortion of the composite mass that forms the north end of the Ox Mountains (Slieve Gamph) in the county of Leitrim gives a similar impression of viscid flow The melting of a single constituent of the invaded schists, which here include amphibolites, would enable them to yield in response to the pressures that were forcing the granite magma in thin sheets between them Their metamorphism is thermal, and the forces that have produced the crumplings are not those of shearing acting on a solid mass, but may have operated from a distance hydrostatically through the magma

Again, where limestones occur near granite contacts amid a series of various sedimentary types, they display folded structures in an altogether exceptional degree. Silicates have developed along their bedding-planes, but these have become contorted and rolled upon one another as metamorphism reached its maximum stage At Maam Cross and Oughterard in the county of Galway, along the margin of the great granite mass that stretches thence southward to the sea, these flow-structures are conspicuous on weathered surfaces. The remarkable structures, moreover, of the 'skarn' of Fennoscandia, though otherwise explained by Trüstedt [29], may possibly represent an extreme stage of thermal alteration acting upon ordinary limestone.

Sederholm [30] refers contortion on a large scale to the latent plasticity of the rocks in the deeper layers of the crust, that is, in the 'plastosphere,' where the pressure is sufficient to translate this plasticity into flow His researches on the basement-levels of the crust suggest, moreover, that in the depths heating becomes a very important factor in aiding this plasticity.

The main object of the foregoing discussion is to point out that the Huttonian cycle, in which thermal changes play so large a part, implies a serious weakening of the crust as magmas advance into it from below. The extensive metamorphism of the pre-Cambrian strata, which amounts to a distinctive feature, must, I think, be attributed, not to special intensity of tangential pressures in early times, but to frequency of igneous attack Much of the crumpling of our schists may result from Hutton's 'softening,' the pressure being supplied from superincumbent masses, or even hydrostatically, and the flow occurring laterally, or vertically downwards, towards regions where destruction by absorption was going on. The features seen during the falling in of the walls of the lava-lake of Kilauea in Hawaii afford some idea of what takes place in zones of melting within the crust

Were the scenes familiar to travellers at Kilauea to occur on a continental scale, they would be regarded as part of the regular order of nature, but would

[29] O Trustedt, *op. cit.*, *Bull Comm. géol Finlande*, No 19 (1907), p 91

[30] 'Weitere Mitteilungen über Bruchspalten,' *Bull Comm géol Finlande*, No 37 (1913), p. 66.

none the less appear catastrophic in their intensity. Were they subterranean, they would be felt at the surface in more or less degree, according to the depth of the melting zone. In early pre-Cambrian times, whether a cooling molten earth was resenting its first imprisonment in a crust, or whether the collision of meteorites or the concentration of radio-active matter towards the surface was beginning to make itself effective, the zone of melting appears to have influenced great thicknesses of overlying strata. This influence was not world-wide at one and the same epoch, as we may see by the preservation of slightly altered sediments in certain places; but it was vigorous, menacing, and recurrent.

Under such conditions, even the surface-rocks must have fallen in at some points and have been replaced by igneous extrusions. Isostatic adjustments must have been very frequently disturbed. Folding of rocks, as a phenomenon of lateral surge and flow, must have made itself freely felt at the earth's surface. It is safe to assert that such conditions have not been repeated on a broad scale at any geological period subsequent to the spread of the Olenellus-fauna. Geochemical evolution, however, may have surprises still in store, and, in spite of long tradition, we are disinclined nowadays to rely too strongly on arguments based upon the sanctity of human life.

Possible Breaks in the Slow Continuity of Earth-movement.

1 *The Mountain-building Stage.*

Even with the thickened sedimentary crust beneath us, and the confidence inspired by our limited experience of the earth, we may ask if subterranean changes may not still result in catastrophes at the surface. Volcanic paroxysms have been regarded complacently as safety-valves, and the destruction of thirty thousand persons in a few minutes in Martinique or the Straits of Sunda form interesting historic episodes, when viewed from the platform or the pulpit of survivors in other lands. The 'grand theatre of action,' as Lyell says, may shift; but we feel that it will not do so in our own time. Some people live under towers of Siloam, others in San Francisco; but, after all, the menace appears small to the teeming humanity of the earth The rise of an imperial dynasty at our side in Europe is more to be dreaded than that of isogeotherms beneath us.

What, however, is likely to occur if a mountain-building episode again sets in? Such episodes, affecting very wide areas, have undoubtedly recurred in the earth's history. We do not know if they are rhythmic; we do not know if they represent a pulsation, decreasing in intensity, inherited from the stars and hampered by increasing friction; we do not know if they record internal chemical changes, which have no climax, because they are neither cyclic nor involutionary, but evolutionary. The mid-Huronian chains, now worn down and supplying such valuable horizontal sections, were evidently of great extent; but we cannot say that they were vaster than those of later times

The phenomena accompanying the growth of a single chain in the Cainozoic era give us, at any rate, ample food for thought. Though the narrow cross-section of the core of such a chain limits our field of observation, the same inpressings of igneous material, and the same features of rock-weakening and rock-destruction, may be observed as in the immense basal sections exposed in the Archæan platforms. The progress of geological time has not diminished the activity in the depths. The granodiorite of western Montana,[31] for instance, which intruded during an uplift in early Eocene times, has attacked the Algonkian sediments of the district, producing phenomena of stoping and assimilation in the true 'Laurentian' style.

In the western and central Alps, again, the absence of any fossiliferous strata older than the Carboniferous arouses some surprise, until we find that many of the granitic intrusions are of late Carboniferous age. The crystalline schists

[31] J. Barrell, 'Marysville district, Montana; a study of igneous intrusion and contact metamorphism,' *U.S. Geol. Surv.*, Prof. Paper 57 (1907), and W. H. Emmons and F. C. Calkins, 'Phillipsburg Quadrangle,' *ibid.*, Paper 78 (1913).

west of Časlav in Bohemia and in the Eisengebirge are now attributed by Hinterlechner and von John[32] to the metamorphism of Ordovician strata by younger granite, which intruded in post-Devonian and probably in Carboniferous times. Much of the gneiss and granite of the Black Forest and the Vosges is now, moreover, removed from the Archæan, and is shown to be associated with the Armorican movements.[33] These vast intrusive masses occupy the place of strata of pre-Permian age. The great development of thermal metamorphism in the Erzgebirge and in Saxony,[34] two classic regions of the dynamometamorphic school, is now widely recognised, and this activity is also assigned to late Carboniferous times. The work of C. Barrois in Brittany is concerned with absorption-phenomena resulting from intrusions during the same mountain-building epoch.

Sederholm[35] has suggested that the ground above an area affected by processes of mountain-building cracks and becomes faulted, while the more plastic zone below flows under pressure into folds. But the blocks of the 'brittle' layer, as Lawson has it, may be seriously displaced by movements in the zone of folding, and subsidences of a regional character may occur. The example of the Minaun Cliffs in Achill shows that the plastic zone may become locally thickened by softening and overfolding. The pressure that has driven an excess of matter to the region of overfolding has squeezed it from beneath an adjacent region. Crumpling and overfolding are accompanied by a shearing away of the matter in one zone from that of another which overlies it; this must result in considerable disturbance of the zone nearer the surface.

We usually regard such disturbances from the uniformitarian point of view Earthquakes are often bad enough, but they are treated as breaks in a slow process of folding that is always going on beneath our feet. May not, however, actual mountain-building be the break in a slow process of 'softening,' to use Hutton's term? For a long time the isostatic balance suffers only small disturbances, restoring itself automatically on a gently-yielding underworld. Then something gives way; something—a large mass of supporting rock—suffers a change of state. The balance is destroyed abruptly, and mountain-building and rapid subsidences have their day. O. Ampferer,[36] with his customary largeness of view, has referred superficial evidences of disturbance, such as mountain-ranges, to dragging movements of a mobile *Untergrund*. He urges that physical and chemical changes within the earth may produce considerable local changes of volume. Vertical movements lead to upfolding, and this leads to gravitational sliding. The zone of folding that we have been considering as normal near the *Untergrund* thus becomes transferred to the surface of the earth.

I am not now concerned with the causes of folding, beyond the fact that at a certain critical stage the material involved may move at a rapid rate. When R. A. Daly speaks of an 'orogenic collapse,'[37] he implies something of a different order in time from the slow processes of sinking and accumulation of sediment that have gone before. Changes of state, physical and chemical, occur with some abruptness. In the case of rocks, the softening or melting of even one constituent may allow of flow, and, as we have observed, this flow in a lower layer may soon become manifested in surface-changes.

Ampferer and Hammer[38] have recently considered the question of collapse in an opposite sense to that of Daly, who pictures it as the herald of an upward movement. These authors, on the other hand, regard the overfolded structure of

[32] *Verhandl. k. k. Reichsanstalt*, 1910, p. 337, and *Jahrb. ibid.*, vol. lix. (1909), p. 127.

[33] P. Kessler, 'Die Entstehung von Schwarzwald und Vogesen,' *Jahresberichte Oberrhein. geol. Vereines*, vol. iv. (1914), p. 31.

[34] C. Gäbert, *Zeitschr. deutsch. geol. Gesell.*, vol. lix. (1907), p. 308; R. Lepsius, 'Geologie von Deutschland' (1910), Pt. 2, pp. 107 and 172.

[35] *Op cit.*, *Bull. Comm. geol. Finlande*, No. 37, p. 66.

[36] 'Das Bewegungsbild der Faltengebirgen,' *Jahrb. k. k. geol. Reichsanstalt*, vol. lvi. (1906), p. 607.

[37] *Igneous Rocks and their Origin* (1914), p. 188.

[38] O. Ampferer and W. Hammer, 'Geologischer Querschnitt durch die Ostalpen,' *Jahrb. k. k. Reichsanstalt*, vol. lxi. (1911), p. 700.

mountains as due to a considerable local reduction in volume of the *Untergrund*. The upper crust presses inwards from opposite sides, and the parts that are thrust downwards become absorbed and carried away with the retreating region of the *Untergrund*. The surviving parts fall over on either side, producing, as the whole continues to close in, folds that are not so very different from the now familiar *nappes de recouvrement* which these authors hesitate to accept. It is not clear why the postulated reduction in volume in the substratum should occur along a certain line, so as to give rise to axial folding at the surface. The folded mass, broken up by overthrusts, as sketched by Ampferer and Hammer, suggests in its general outlines a Jerusalem artichoke rather than a breaking wave.

The important point for our present purpose is, however, the restatement of the results of gravitation on the flanks of an uprising chain. The chain is said [39] to result from 'overthrustings with occasional involutions, accompanied by the rolling over and pushing forward of blocks' ('Ueberschiebungen mit gelegentlichen Einrollungen, Walz- und Schubschollen'). So long as these movements occur in the depths, they may be retarded considerably by friction; but, when they produce mountain-bulging at the surface, freedom is given to the 'waltzing' masses, and gravitation comes into play on the unsupported strata that flank the dome or anticline.[40]

Ampferer and Hammer [41] point out incidentally that much of the covering of Flysch and Molasse strata was worn away from the Alps before the final folding which gave the chain its eminence in early Pliocene times. They argue that the uplifted masses were thus less imposing than those pictured by G. Steinmann or C Schmidt in their diagrams of the *Decken* or recumbent folds. But the view advanced by Ampferer and Hammer allows the principal folding to take place in contact with the upper air. The cover is usually supposed to act as a restrainer, and the long duration of the folding movements is held to have allowed of contemporaneous denudation. Cases, for instance, are known to us where rivers have maintained their level while crust-blocks rose beneath them.[42] The surprising thing, however, about our folded mountain-chains is the way in which they have been eroded parallel to the strike of the overthrust sheets or overfolds. Apart from occasional detached 'klips,' the distal parts of these masses must have been at one time continuous with those proximal to the root-region. The forward movement could not have occurred if denudation had negatived the effects of folding on the surface. A. Tornquist [43] has suggested that Jurassic limestones were pushed in among unconsolidated mudbanks while the Eocene sea still lay across the Alpine area. Anything comparable with this during the final folding could not fail to produce a largely felt disturbance at the surface. It is impossible to believe that the ground does not part asunder in Sederholm's zone of fissuring during the exceptional movements that rear a folded mountain-chain. Where such a zone has remained with its parts in contact, as in Fennoscandia, mountain-building has not really taken place Intense folding may have occurred in the plastic zone below; but no one of the lines of superficial weakness has been continued as a plane of fracture into the depths. When this continuation occurs, the material of the folded zone may be forced up to the surface. The general deep-seated crumpling then involves the beds over it and becomes concentrated as an axial chain.

The marine or lacustrine deposits of the age immediately preceding that of uplift obviously cannot be consolidated at the epoch of upheaval. Gotlandian sands and muds must have overlain the heaving masses that rose as Caledonian land. The swamps of the Coal Measures were contorted in the Armorican chains; the highest beds of these must have been as yielding and as capable of

[39] *Ibid.*, p 701.

[40] Compare O. Ampferer, 'Das Bewegungsbild von Faltengebirgen,' *Jahrb. k. k. Reichsanstalt*, vol. lvi. (1906), p. 601.

[41] *Op. cit* (ref. 38), p. 708.

[42] This is urged even for the Himalayas. Medlicott, Blanford, and Oldham, *Geology of India*, ed. 2 (1903), p. 463.

[43] 'Noch einmal die Allgäu-Vorarlberger Flyschzone und der submarine Einschub ihrer Klippenzone,' *Verhandl. k. k. Reichsanstalt*, 1908, p. 330.

flow as the Flysch that overlay the growing Alps. In all these cases, familiar to us in Europe, the covering masses must have responded to the crumpling under them, and, when reared to dangerous eminences, rapidly became a prey to denudation and gravitational downsliding. They can scarcely be regarded as protective, and their removal would leave the brittle masses below more liable to fracture and to the 'calving' process that forms klips.[44]

Whether or no we postulate a yielding cover, the folding or overthrusting thus becomes part of the phenomena on the surface of the globe. This fact is glossed over in some of the admirable diagrams and models that have been prepared for our instruction, where the Flysch, for instance, above the overfolds is left without structural lines. Yet I venture to think, as I have already written,[45] that in the Alps 'so much occurred within a single epoch, the Tortonian or Upper Miocene, and probably in a few thousand years, that some of the movements must have been visible to the eye of man, had so discerning a creature appeared upon the scene. Earthquake-shocks at the present day produce perceptible undulations of the ground, and may leave permanent traces in the form of faults and dislocations. But it seems doubtful if a succession of small movements such as man has been able to record represents anything like the building of a mountain-chain when the resistance of the rocks has been overcome. . . . Slow as the general movement may have been, the crumpling was not confined to the hidden layers of the crust. It occurred in the rocks that formed the very surface, and the final drop into the lowlands suggests the features of a landslide.'

This conception was natural to the minds of our predecessors before a salutary check was given to those who demanded frequent and world-wide 'revolutions.' But nothing since that time has altered our impressions of the vast forces latent in the earth, ready to perform work when unbalanced and set free. The pressure that produces the solid flow foreseen by G. P. Scrope,[46] and demonstrated in C. Lapworth's mylonites, is capable of rearing folds to dangerous elevations at the surface.

The danger lies in the form of the fold in relation to its base. Ampferer and Hammer[47] urge that the basal rocks are absorbed into the depths, since the folded strata, when spread out again, would cover a far larger area than the crystalline cores beneath them. The upper layers therefore tend all the more to slide and fold on one another. Gravitation alone becomes under such circumstances a potent cause of surface-crumpling.

G. P. Scrope[48] felt that the uprise of a chain was in itself sudden and paroxysmal. We may go so far—or, shall we say, go back so far?—as to realise that large shifts may be made suddenly along thrust-planes when crushing takes place and resistance has been overcome. We can feel greater confidence, however, when we consider the gravitational movements outwards from the line of upfolding. These may be either one-sided or two-sided. Scrope[49] represents the lower zone in a mountain-chain as flowing by pressure towards a line of weakness, and the upper zone of rocks as flowing by gravitation away from this line on both sides. He believed that, in addition to crumpling and the production of recumbent folds, actual fissuring might occur. He explained in this way the isolated blocks of the Dolomite Alps of Tyrol. 'Fracture chasms' may not have occurred between these particular blocks, though differential move-

[44] Something of this kind must have been pictured by C. L. Griesbach, when he wrote ('Exotic Blocks of the Himálayas,' *C.R., Congrès géol. internat.*, 1903, p. 551): 'Much of the older sedimentary rocks must have been brought to the surface, not only as part of the sections, but also in crushed masses and detached blocks torn off from situations *in situ*, a phenomenon common to all disturbed areas. The outcrops of dislocations which have later undergone weathering and denudation must, of course, have been shorn of all crushed and loose fragmentary masses.'

[45] *The Growth of Europe* (1914), p. 173.

[46] *Considerations on Volcanos* (1825), pp. 202 and 234.

[47] *Op. cit.* (ref. 38), p. 708.

[48] *Considerations on Volcanos* (1825), pp. 202 and 234.

[49] *Ibid.*, pp. 202 and 204.

ments—perhaps even 'waltzings'—along fault-planes have been proved; but is there anything in Scrope's position that is really more extreme than the klip-theory of the present day?

Klips must be regarded as blocks cut off from the main region of an overfolded or an overthrust mass. Denudation occurring after the forward movement suffices to explain some cases; in others, separation seems to have taken place as the moving mass fell forward. The klips of hard material embedded in softer strata are thus a kind of rock-spray, hurled in advance of the breaking earth-wave. C. Schmidt[50] in our own time pictures the transference by gravitation of strata from above the St. Gothard gneiss to the lowland of the Lake of Uri. This lowland has become enriched, then, from a scenic point of view at the expense of the unstable central range.

In times later than those of the fathers of geology, the apostle of gravitational movement as a cause of overfolding has undoubtedly been Edvard Reyer. He has recently restated his views on the origin of mountain-ranges,[51] and he must be satisfied with the general concurrence that sliding is a factor to be considered. He may be especially pleased with P. Termier's[52] description of the overriding of the Pelvoux mass by earth-waves from the east, where the isoclinal folding of the strata on the west side of the chain is referred to the passage of sheets across them, which have since disappeared through denudation. The folding, says Termier, in his admirable prose, records the outward movement of the sheets, just as the forms of the trees in the Provençal plain record the passage of the mistral. Termier in no wise fears to speak of the progress of a 'traîneur écraseur' during mountain-building as 'soudain et rapide comme une rupture d'equilibre, le dernier acte, longuement préparé, mais joué d'*emportement*, de ce drame grandiose.'

Rupture combined with rapid movement of the rocks need not be the last act of the drama; but, the more we examine the history of folded chains, the more probable it appears as a culminating episode. The infolding and infaulting of strata, such as the Siwalik Beds in India, at the base of a rising chain may be a matter of slow squeezing. We see in India how denudation has been at work during the overthrusting process; but the successive movements may none the less have included rapid phases. When a fan arises in a geanticlinal by nipping at the base, its destruction also may be rapid, since it is assisted by rupture and falling apart of the upper portions of the folds. The original cover of our present ranges has been lost by denudation. Earth-sculpture in these regions of high altitude and vehement attack has removed much of the evidence that we seek. What remains, however, may lead us to feel that no part of the world in historic times has experienced a mountain-building episode.

Such relatively catastrophic stages have, indeed, not been common in the long history of the earth since pre-Cambrian times. It appears that now and again the 'orogenic collapse' of some considerable area disturbs the balance in the crust and spreads far through the upper layers like a disease. Or it may be that the thermal cause of the collapse is common to the whole earth at the same time, and becomes manifest in responsive regions far apart. In any case, the weak places give way and the more resisting ones close in. A readjustment is effected, which then endures through long geological time.

Radio active measurements of the length of geological periods may some day enable us to determine if the major disturbances of the crust are rhythmic. Present results, however, do not indicate a time-relation. The figures provided by W. J. Sollas,[53] and based on the thicknesses of strata, give us the following intervals between some of the best marked foldings of the crust. The unit here employed is the time represented by 1,000 feet of strata. The formation of the Huronian chains must be set back by an unknown amount into the pre-Cambrian era, since the crumpled masses, invaded by the younger series of

[50] *Bild und Bau der Schweizer Alpen* (1907), p. 68.

[51] *Geologische Prinzipienfragen* (1907), pp. 142, 147, &c.

[52] 'Les Problèmes de la Géologie tectonique dans la Méditerranée occidentale, *Revue générale des Sciences*, March 30, 1911.

[53] Presidential Address, *Quart. Journ. Geol. Soc. London*, vol lxv (1909) *Proceedings*, p. 112.

'Laurentian' granites and gneisses, were greatly denuded before the lowest Upper Huronian (Animikian) strata were laid down.[54] This renders the first time-interval here given of very little value, and its resemblance to the third interval seems a matter of mere coincidence.

Interval from Middle Huronian to Caledonian (Lower Devonian) folding, (?) 122 units.
From Caledonian to Armorican (latest Carboniferous) folding, 51 units.
From Armorican to Alpine (earliest Pliocene) folding, 127 units.

Our search for a rhythm is complicated by the occurrence of more localised movements of considerable intensity at intervening geological epochs. The Caucasus, for instance, became strongly folded towards the close of the Jurassic period, when western Europe responded by a gentler groundswell. The Cretaceous beds on the flanks of the Harz Mountains were upturned in early Eocene times, when our English Chalk also came within reach of denudation Heralds of this unrest may perhaps be seen in the vast outpourings of lava in central India towards the end of Cretaceous times; and it is clear that we must take into account such igneous upwellings, and also the occurrence of down-sinkings of large areas, when drawing up a history of energy within the earth.

As already observed, this energy seems effective enough at all epochs The Armorican folding was accompanied by immense upwellings of molten matter from the depths, and the features of crust-weakening and absorption seem to have rivalled those that we can study in the basal sections of Archæan mountains. The Alpine movements were probably associated with equally intense igneous action, the extent of which will not be revealed until the present destructive phase of the Huttonian cycle is complete.

The imminent menace of crustal changes was brought home to us during the terrible period from April 4, 1905, to January 14, 1907, the final twelve months being marked by a veritable earth-storm.[55] Three years had elapsed since the catastrophic events of Saint Vincent, Martinique, and Santa Maria of Guatemala. On April 4, 1905, 20,000 persons perished through an earthquake in the Kangra Valley, on the flanks of the central Himalayas. On September 8 destruction was carried through Calabria. On January 31, 1906, the Colombian coast suffered from sea-waves flung upon it by the Pacific floor, and in March and April the unrest was manifested on the other side of the basin in Formosa From the 4th to the 12th of April, Naples was endangered by one of the most serious eruptions of Vesuvius, which reduced the mountain by 500 feet and formed the present crater of explosion. On April 18 San Francisco was wrecked in sixty-five seconds, and the fires that broke out in the shattered city completed its destruction in five days. On August 16 Valparaiso and Santiago similarly suffered, and sea-waves signalled the earth-movement seven thousand miles away on the margin of Pacific isles. On January 14, 1907, the year of earth-storm closed with the ruin of Kingston in Jamaica.

The last great storm of mountain-folding, that which reared the Cainozoic ranges and marked out the edges of Eurasia and America, seems still to produce symptoms of unrest. Geologically speaking, however, we are near enough to the Tortonian epoch to look forward with some confidence to a quiescent phase But some day, in its due season, the earth will once more be active. When that time comes, no ingenuity of man will suffice to meet it. Earthquake after earthquake, increasing in intensity, will probably have driven the population to a distance from the threatened zone. Concentration of the folding along a particular earth-line will limit the region of absolute destruction; but the undulations spreading from it, in response to the heavings of the chain, will offer sufficient chances of catastrophe In the case of our youngest mountain-

[54] A. P. Coleman, Presidential Address to Section C, *Rep. Brit. Assoc.*, 1910, p. 598.

[55] The details are summarised in G. A. J. Cole, *The Changeful Earth* (1911), pp. 195-203.

ranges, these undulations remain perpetuated as domes and dimplings of the crust, which are already worn down or infilled respectively by denudation and deposition. Their present forms and places record the last movements of the earth-storm, just as a buckled tramway-rail records the passage of an earthquake. How shall we gauge to-day the intensity of their rise and fall?

In the case of the city devastated by an earthquake, the débris is cleared away, and our descendants in time discover the distorted rails beneath the healing mantle of new grass. Will they realise from this alone the preliminary tremors, the sudden arrival of the culminating vibration, the shock that overcame the elasticity of the crust beneath them, and then the gradual establishment of the conditions under which they have passed their peaceful lives? The crumpled wreckage lies there in evidence before them; but how will they distinguish the work of a few stormy seconds from that due to the gentle earth-creep of a century?

Possible Breaks in the Slow Continuity of Earth-movement.

2. *Regions of Subsidence.*

It was probably E. Suess who brought home to most of us the importance of regions of subsidence in defining the lowlands and the sea-basins from the upstanding masses of the crust. While one region may be folded, another may be broken into blocks; and the two types of movement, that due to tangential thrusting and that due to vertical uplift and down-faulting, may appear in the same region and may alike play their part in producing a lowering of large areas. The domes and dimples that occur beyond the region of acute crumpling may be intensified into fault-blocks by fracture of their boundaries. W. Salomon [56] has, moreover, shown us how the movements in the Rhine-trough, a typical region of block-foundering, may be linked with those associated with over-thrusting. The rise of one region is associated with the lowering of another. If catastrophes are possible during uplift, we may look for them also during subsidence.

The occurrence of lines of volcanoes in and along the edges of subsiding areas may be regarded as evidence of the squeezing of a previously fused substratum, or as evidence of sub-crustal melting which has primarily caused the subsidence. In either case, it is difficult to believe that the cracks along which the cones become established are formed gently and without elements of surprise. The dykes and cones represent a healing process. The accumulation of lava-sheets and the outpouring of ash from localised centres obscure what has gone on before. The uplift of the Pacific coast has included rapid stages, as C. Darwin recognised,[57] and as we have recently realised in Alaska. It is improbable that the downward movements of the sea-floor adjacent to it have been of a minor order, or that the larger movements of elevation have not been accompanied by similar movements of collapse.

The cutting-up of mountain-chains by transverse fractures has resulted in the loss of huge blocks beneath the sea. In such cases it is clear that faulting has run a long way ahead of denudation. The breaking of the chain that united Andalusia and the western Alps, the falling in of the Tyrrhenian earth-block, the subsidences at two separate epochs of the southern and northern Adriatic, and the conversion of the hilly mass between the Balkans and Asia Minor into the Ægean, set with islands, suggest a return to the girdling waters of the Tethys. The spread of the Atlantic northward, by fracture across the tough blocks of Armorican land, has led Pierre Termier to revive the story of Atlantis [58] as an episode of human times. Botanists and zoologists require a recent Atlantic land-surface as a field for migration and a refuge during Glacial cold. Who has recorded, except the Egyptian priest of Sais, the precise mode of its disappearance beneath the waves?

All trough-valleys, which are often called, somewhat misleadingly, rift-valleys, raise the same questions as to the nature of the steps by which they have been produced. The Rhine Vale, one of the most closely studied examples,

[56] 'Die Bedeutung der Messen von Harnischen,' *Zeitschr. deutsch geol. Gesell.*, vol. lxiii. (1911), p. 515.

[57] *Geol. Observations on S. America*, Minerva edition, p. 293.

[58] 'L'Atlantide,' *Bull. Institut océanographique*, No. 256 (1913).

dropped 8,000 feet within the limits of Oligocene time. It is improbable that the numerous faults now traceable operated with concerted gentleness, or invited the Oligocene sea to lap in by imperceptible gradations from the west.

Abruptness of certain Geographical Changes.—River-capture.

There is a totally different class of terrestrial phenomena which lends itself also to speculation, or to that imaginative faculty, proper to our Section, which enables the geologist to reconstruct. The deluge that appeared to affect the world, as known to Chaldæan sages, has long been regarded as confined to a limited valley of western Asia. But geographers have taught us to speak lightly of river-diversion and river-capture, and to treat them as frequent occurrences in the history of existing lands. It is interesting to inquire what this process on a large scale may involve.

The draining of the Ragunda lake in Sweden[59] in 1796, by the rapid cutting of a ravine 100 feet deep in a soft barrier, shows how many of our Glacial lakes, dammed by morainic matter, may have excavated their outlet gorges and run dry in the course of a few hours. The history of the temporary lake behind the Gohna landslip, so brilliantly studied by our Vice-President, Sir Thomas Holland,[60] provided a lesson both in hill-destruction and catastrophic flooding. The diversion of the Colorado River, however, in 1905, into the sluice leading to the Salton Sink gives us a definite illustration of river-capture. The 'New River' thus produced in the depression to the north-west of Calexico cut a valley seventy feet deep through the agricultural land that it was meant to serve, and worked the head of this valley backward at the rate of a third of a mile a day.

One of the most remarkable instances of river-diversion in the European record is that of the waters from the north side of the central Alps. At the close of the Pliocene period, the chain had already become grooved by the subsequent valley of the Rhone, and this river had been shifted, by earth-movement in the Juras, south-westward towards its present course at Geneva. The north slopes of the St. Gothard mass and the Bernese Alps, supplying the torrents of the Reuss-Aar-Saane system, still, however, drained across the hummocky land near Bâle and sent their waters over to the Doubs. The great Rhine-trough drained southward, and its streams formed tributaries of the Alpine flow near Bâle.

The Mainz basin, however, which was infilled by Lower Pliocene alluvium, became tapped by the head of a river that had long run northward from the Hunsruck-Taunus range. This river is the Rhine that we know north of Coblenz, and its alluvium was then spread out where the sea now stretches between Holland and the Yorkshire coast. Its mature valley is still traceable[61] above the present stream-cut in the hills. This river could have no direct influence on the course of the drainage from the Alps. But the bulging of the land at the north end of the Juras still continued. As the text-books remark with some complacency, the Burgundian gate was closed, and the river that had previously crossed westward was diverted northward to the Rhine-trough.

Can we exactly picture what this means? The whole Reuss-Aar-Saane system 'on some particular day began to flow northward along the far older tectonic trough, carving away the infilling of detritus, washing back tree-stems that were floating quietly from the Lake of Mainz on their way to the Mediterranean, and finding, when it reached that lake, a notch sufficiently low for its escape across the Hunsruck-Taunus range. An enormous body of water was thus added to that which had formed in Pliocene times a mature valley across these hills.'[62] The addition of the drainage of Graubünden, including the

[59] See especially H. W. Ahlmann, 'Ragundasjöns Geomorfologi,' *Sveriges Geol. Undersök*, 1915; also Ahlmann, Carlzon, and Sandegren, 'Quaternary History of the Ragunda Region, Jämtland,' *Geol. Fören. Förhandl.*, vol. xxxiv. (1912), p. 343.

[60] *Records Geol. Surv. India*, vol. xxvii. (1894), p. 55, and *Nature*, vol. l., p. 501.

[61] W. M. Davis, *Die erklärende Beschreibung der Landformen* (1912), p. 106.

[62] G. A. J. Cole, *The Growth of Europe* (1914), p. 109.

Vorder and Hinter Rhein and the Lake of Constance, to the water flowing through the trough-valley was probably an accident that occurred later than the Riss-age of the Glacial epoch. The system indicated above, representing the flow from a hundred miles of snow-clad mountains, must, however, have made a remarkable change in the stream across the Armorican hills. In time, as it lowered the loose deposits of the Mainz basin, this river carved out the young ravine that runs like a knife-cut through the range; the water that flows past Mainz, with the exception, perhaps, of that from Constance, represents the magnitude of the event that we speak of as the diversion of a stream. The abrupt change was not confined to the hill-region. When the Alpine water arrived at the Mainz basin, and found its way into the notch formed by the Pliocene Rhine, carrying with it mud from the glaciers of the Jungfrau and coarser alluvium from the old trough-valley, it poured down upon the forest-covered delta-land.

The changes that have occurred in the unconsolidated ground of Holland in historic times, including the loss of the Biesbosch, with its seventy-two villages, in a single night, furnish some picture of what must have happened in the prehistoric delta of the Rhine. Land was suddenly built up at some points, islands were carved out at others, and the effects of the catastrophe must have been still manifest when the Scandinavian ice-sheet began to invade the mud-flats from the north.

The capture of a large river may be illustrated by the story of the Vistula. This noble stream, the Rhine of Polish lands, represents in a remarkable way the drainage of 190 miles of the Carpathians. All this water becomes concentrated, at the apex of a reversed river-fan, at the east end of the Kielce hills, and it is probable that the upper Vistula was driven to join the San by the advancing ice-front of the Riss-age, and that both rivers then escaped southwards. The joint waters were again held up when the Fennoscandian ice rested along the line marked by the Baltic Heights, and it is well known that a great river flowed westward along the stagnating ice-front where now the marshes of the Netze mark its course. This river stretched away west to join the Elbe, and the water from the Galician highlands thus met that from Switzerland in the Anglo-Danish delta-land. As the ice-front shrank backward, towards the Baltic basin,[63] streams flowed down over the sands and boulder-clays and cut their valley-heads back southward. Overflows may have taken place on the unconsolidated wall of the great east-and-west river, which was now deprived of its barrier of moraine-filled ice. In one way or another, the shallow valley of the main river was tapped near Kustrin, and the Oder, rising in the Moravian plateau, was sent northward as an independent stream. Similarly, the Vistula was carried off at Fordon, where the bend due to capture is conspicuous at the present day; and the whole drainage of the north wall of the Carpathians swept across the drift deposits down the course of some hitherto unimportant stream. Along the valley thus carved out, brown and yellow cliffs now rise above the marshy flood-plain, and the red castles of advancing Germany have for centuries looked down firmly on the stream. It is quite contrary to our customary philosophy, but a good corrective all the same, to ask ourselves if this lower valley of the Vistula, eighty miles in length, was shaped in a few months or a few years. The main part of the excavation, across unconsolidated lands, may have occupied less time than the building of the strongholds at the fords.

Conclusion.

In spite of the swamping of the Alkmaar country in 1825, in spite of the tragedy of Messina only seven short years ago, we feel that Europe is a settled continent, and we judge the past and future by the present superficial peace. We have applied the same thoughts to human movements, and the inconceivable has happened in our midst. We naturally find it difficult to carry our minds back to epochs when the earth-blocks may have parted asunder as ice parts across the polar seas. We have, however, still very much to learn about causes now in action; and the mystery of the earth, and of our connexion with it,

[63] R. Lepsius (*Geologie von Deutschland*, Pt. 2, p. 511) urges that the sinking of the floor of northern Europe led to this northward trend of the streams.

grows upon us as we learn. Can we at all realise the greatest change that ever came upon the globe, the moment when living matter appeared upon its surface, perhaps over a few square miles? Matter is either dead or living, that is, endowed with life; there is no intermediate state. And here was living matter, a product of the slime, if you will, but of a slime more glorious than the stars. Was this thing, life, a surface-concentration, a specialisation, of something that had previously permeated all matter, but had remained powerless because it was infinitely diffuse? Here you will perceive that the mere geologist is very much beyond his depth. Let us return to our orderly studies, our patient hammerings, our rock-slices, our chiselling out of fossil shells. Behind it all is the earth itself, quiescent, it may be, but by no means in the sleep of death. As Termier puts it, 'La planète n'est pas encore morte; elle ne fait que dormir.' If in this Address I have dwelt upon the possibility of rapid changes in its surface, no member of our Association will feel the least alarm.

Felix qui potuit rerum cognoscere causas,
Atque metus omnes, et inexorabile fatum,
Subiecit pedibus, strepitumque Acherontis auari.

The following Papers were then read :—

1. *On the Geology of Manchester and District.* *By* Dr. G. Hickling

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2. *On the Discovery of* Solenopora *and* Sphærocodium *in the Silurian Rocks of Britain.* *By* Professor E. J. Garwood, *F.R.S.*

At the meeting held at Birmingham in 1913 attention was called to the important part played by calcareous algæ, especially *Solenopora*, as rock builders in the Ordovician and Carboniferous Rocks of Britain, and at the same time it was pointed out that no example of this genus was, so far, known to occur in rocks of Silurian age in this country. It was prophesied, however, that these organisms would ultimately be found in rocks of this age if careful search for them were instituted in suitable districts. This prediction has now been amply justified, and it is now possible to state that, not only does *Solenopora* occur both in the Wenlock and Woolhope limestones of the type Silurian district, but that in certain areas, namely the borders of Herefordshire and Radnorshire, we find what is perhaps the most remarkable development of algal limestone yet met with in Britain. In this border country we find a mass of crystalline limestone upwards of eighty feet thick, in which occur beds often largely made up of the remains of *Solenopora*—some of these algal growths reaching a diameter of over six inches. This species of *Solenopora*, which appears to be a new form, is accompanied by remains of *Girvanella* and *Sphærocodium*; this latter genus is now recorded for the first time from Britain, and occurs both in the Old Radnor limestones and also in the Wenlock Limestone of May Hill. It resembles very closely *Sphærocodium Munthei* from Gothland. The species of *Solenopora* which occurs in the Wenlock limestone at Farley Quarry is identical with that from Radnorshire, and appears to be closely related to *Solenopora Gothlandica*, while that from Woolhope is a much coarser form.

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3. *The Classification of the Tertiary Strata by means of the Eutherian Mammals* *By* Hon. Professor W. Boyd Dawkins, *M.A., D.Sc., F.R.S.*

The classification of the Tertiary Strata by means of the higher mammalia outlined in my paper before the Geological Society in 1880[1] has been tested by the many discoveries all over the world since that time, and not found

[1] *Q.J.G.S.*, pp. 379-404.

wanting. The details have been filled in, and the principle adopted has been proved to be of world-wide application—to apply to North and South America and to Southern Asia and Africa as well as Europe—the living mammalian species in each geographical province being taken as a standard. It has been accepted by Osborne and others, and is now being used for the grouping of the Tertiary strata of America. It has been used in the organisation of the Manchester Museum. It is therefore fitting that it should be brought up to date.

The classification is based on the evolution of the mammalia, the only group in the animal kingdom that was, as Gaudry writes, 'en pleine évolution' in the Tertiary Period, all the lower forms having already undergone their principal changes and none changing fast enough to be of service in defining the stages. The scheme is as follows :

Those of the Divisions of the Tertiary Period.

Descriptions.	*Characteristics.*
Historic, in which the events are recorded in history.	Modern types of man. Man the master of nature.
Prehistoric, in which man has multiplied exceedingly and domesticated both animals and plants. Wild Eutheria on the land of existing species, with the exception of the Irish elk.	Modern types of man-cultivated plants. Domestic animals—dog, sheep, goat, ox, horse, pig, &c. Wild Eutheria of living species.
Pleistocene, in which living species of Eutheria are more abundant than the extinct species. Man appears.	Extinct types of mankind. (Modern types?) Living Eutherian species dominant. Man.
Pliocene, in which living Eutherian species occur in a fauna mainly of extinct species.	Living Eutherian species present. Extinct species dominant.
Miocene, in which the alliance between living and extinct Eutheria is more close than in the preceding stage.	No living Eutherian genera. Living Eutherian genera appear. Anthropoid apes. Extinct genera dominant.
Oligocene, in which the alliance between extinct and living Eutheria is more close than in the Eocene.	No living Eutherian genera. Living families and orders. Extinct families and orders numerous.
Eocene, in which the Eutheria are represented by living, as well as by extinct, families and orders.	No living Eutherian genera. Living families and orders. Lemuroids. Extinct families and orders dominant.

The most important break in the succession of life-forms occurs at the close of the Oligocene age in Europe and America. From this break down to the present day the continuity is so marked that we may conclude that the present face of the earth is merely the last in a long succession in the Tertiary Period.

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5. *The Geological Evidence in Britain as to the Antiquity of Man.* By Hon. Professor W. Boyd Dawkins, *M.A., D.Sc., F.R.S.*

Professor Boule, in his masterly essay published in *Anthropologie*, xxvi. Jan.-Avril 1915, freely criticised the evidence on which the antiquity of man in Britain has been stated to go back beyond the early Pliocene age, and concludes that it is not of a nature to throw light on so important a problem. The antiquity of man—or, in other words, his place in the geological record—is a geological question to be decided, like all others, on the lines of a rigid induction. In each case it is necessary to prove not only that the objects are of

human origin, but further that they are of the same age as the strata in which they occur, without the possibility of their having been introduced at a later time. In this communication I propose to apply these tests to the evidence.

The Pliocene age of man in East Anglia is founded entirely on the roughly chipped flints in the basal Pliocene strata—on eoliths, mainly of the rostro-carinate or eagle's-beak type of Moir and Lankester. It has been amply proved, in this country by Warren, Haward, and Sollas, and in France by Boule, Breuil, and Cartailhac, that these can be made without the intervention of man by the pressure and movement of the surface deposits, by the action of ice, by the torrents and rivers, and by the dash of the waves on the shore. The type specimens taken to be of human work have been selected out of a large series of broken flints that graduate into forms obviously made by natural fractures. They are, as Boule aptly says, 'hypersélectionnées,' and can only be rightly interpreted by their relation to the other flints on the Pliocene shore-line.

As might be expected, if they are due to natural causes, the 'rostro-carinates' are widely distributed through the basal beds of the crag in Norfolk and Suffolk. They occur also in the Upper Miocenes of Puy-Courny (Auvergne), in the Pleistocene gravels of London, and the present shore-line of Selsey, where they are now probably being made by the breakers. For these reasons I agree with M. Boule that they have not been proved to have been made by man, and that therefore they throw no light on his place in the geological record.

The presence of man in East Anglia during the Glacial period is founded on even worse evidence than this. The Ipswich skeleton on which Moir and Keith base their speculations was obtained from a shallow pit sunk through the surface soil of decalcified boulder clay—not of boulder clay *in situ*, as stated—into the Glacial sand that crops out on the valley slope. It is, in my opinion, a case of interment that may be of any age from the neolithic to modern times. The skeleton also is of modern type, and belongs, as Duckworth shows, to the graveyard series of burials.

We come now to the consideration of the evidence of the famous discovery on Piltdown of *Eo-anthropus Dawsoni*—the missing link between primitive man and the higher apes. After the examination of the whole group of remains, and a study of the section, I fully accept Dr. Smith Woodward's opinion that the find belongs to the early Pleistocene period. The associated implements are of the same Chellean or Acheulean type as those so abundant in the mid-Pleistocene Brick-earths of the Thames Valley between Crayford and Gravesend. They may imply that *Eo-anthropus* belongs to that horizon, in which the stag is present and the reindeer absent. It must not, however, be forgotten that the classificatory value of these implements is lessened by their wide range in Britain and the Continent through the later Pleistocene river deposits. The stag, the beaver, and the horse of Piltdown—leaving out of account the Pliocene fossil mammals more or less worn into pebbles—are common both to the pre-Glacial Forest-bed and the Lower Brick-earths of the Thames Valley. It must also be noted that the intermediate characters of the Piltdown skull and lower jaw point rather to the Pliocene than the Pleistocene stage of evolution. We must, in my opinion, wait for further evidence before the exact horizon can be ascertained. On the Continent there is no such difficulty.

The earliest traces of man are there represented at Mauer by a mandible associated with the peculiar fauna of the Forest-bed, showing that *Homo Heidelbergensis*, a chinless man, was living in the Rhine Valley during the earliest stage of the Pleistocene. The Neanderthal man, thick skulled and large-brained, with small chin and stooping gait, belongs to the Mousterian stage, that, in my opinion, is not clearly defined from the Chellean and Acheulian gravels of the Late Pleistocene. He ranged from the Rhine through France southwards as far as Gibraltar, and was probably the maker of the Palæolithic implements of those strata throughout this region. It is also probable that he visited Britain, then part of the Continent, in following the migration of the mammalia northward and westwards. While primitive men of these types inhabited Europe there was no place in the Pleistocene fauna

for the thin-skulled men taken by Dr. Keith [1] and others to prove that modern types of men lived in Britain in the Pleistocene age.

Man appears in Britain and on the Continent at the period when he might be expected to appear, from the study of the evolution of the Tertiary Mammalia—at the beginning of the Pleistocene age when the existing Eutherian mammalian species were abundant. He may be looked for in the Pliocene when the existing species were few. In the older strata—Miocene, Oligocene, Eocene—he can only be represented by an ancestry of intermediate forms.

THURSDAY, SEPTEMBER 9.

Joint Discussion with Section E on The Classification of Land Forms.
(See Section E, p. 490.)

The following Papers and Report were then read :—

1. *Notes on the North-Western Region of Charnwood Forest.* *By* Rev. Professor T. G. BONNEY, *Sc.D., F.R.S.*

The author, in a joint paper with Canon Hill, published in 1891, expressed his opinion that the Peldar and the Sharpley porphyroids were probably lava flows, and the dominant rock of Bardon Hill was a volcanic agglomerate. Since that date Charnwood Forest has been examined by the Geological Survey, and the Peldar porphyroid regarded as intrusive in pyroclastic rocks at Bardon Hill. During the present year the author has twice visited the district, having heard how greatly quarrying had progressed, and having become doubtful, from repeated study of his microscopic specimens, about his former conclusions. He had the advantage of being accompanied on one occasion by Canon Hill, on the other by Mr. R. H. Rastall. The additional evidence has changed his view on certain points. He is now convinced that the dominant Bardon breccia (which cannot be separated from the rock similar to its matrix, but without fragments) is really a very exceptional case of a fluxion breccia. In this the microscopic structure of the fragments does not very much differ from that of their matrix, and the latter varies but little from the ground-mass of the Peldar and Sharpley porphyroids, though to the unaided eye these seem quite distinct, or from the rock obtained in the Forest Rock quarry (now opened to the west of that on Peldar Tor), though this sometimes shows more distinct traces of fluxion and a pressure-structure even more marked than at Sharpley. In all three quarries a more compact porphyroid is intrusive into the above-named, and this, at Bardon Hill, is identical with the ordinary greenish rock of that place The latter can be seen sometimes to melt down the Peldar porphyroid, and sometimes to make a sharp junction with it or even to enclose actual fragments.

The author recounted the field evidence and described the microscopic structure of these rocks, which much resemble not only one another, but also some of the fragments common in true agglomerates in that district. The earliest of the rocks is a rather finely crystalline one, which occurs as fragments in the above-named porphyroids; these, which must be very closely related and may be practically of one age, are the next in succession; lastly come the more compact porphyroids, which, at Bardon Hill, and probably also on Ratchett Hill, contain fragments (sometimes in considerable abundance), the latter being but little older than their ground-mass, perhaps only earlier and very slightly differentiated portions of the original magma, which had fallen to the temperature of consolidation.

[1] The skeletons of Galley Hill, in Kent, and that of Cheddar cave in Somerset, have, in my opinion, been buried, and do not belong to the Pleistocene age.

2. *Notes on the Granite Surfaces of Mount Sorrel.* By Professor W. W. Watts, *F.R.S.*

It has been suggested that some of the grooved and polished surfaces known in this circle and in certain other Midland localities may be due to wind action in Pleistocene times. A recently discovered section at Mount Sorrel showed glacial striæ trending N. 10° W. on a set of wind-grooves trending about E and W. Proof is thus given that the Triassic wind-grooves have survived actual glaciation, and may thus be expected to have been able to resist other less drastic methods of recent and Pleistocene denudation.

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3. *The Ordovician Sequence in the Cader Idris District (Merioneth).* By Arthur Hubert Cox, *M.Sc., Ph.D., F.G.S., and* Alfred Kingsley Wells.

Reference was made to the work of previous observers, including Sedgwick, Ramsay, Cole and Jennings, Geikie, and Lake and Reynolds.

The Cader Idris range is formed by a great escarpment of Ordovician igneous rocks, facing northwards across Barmouth Estuary towards the Harlech dome. The igneous rocks were for long regarded as being all of Arenig age.

Re-examination of the area has shown the presence of four distinct volcanic series among the Ordovician rocks, and the following descending sequence has been established:—

Glenkiln-Hartfell	(X.) Talyllyn Mudstones	Grey-blue banded mudstones with *Amplexograptus arctus* in the lowest beds . . . 800 ft.
Glenkiln with Upper Llanvirn	(IX.) Upper Acid or Craig-y-Llam Series	'Andesitic' and rhyolitic ashes and lavas . . . 900–1,000 ft
	(VIII.) Llyn Cau Mudstones	500 ft.
	(VII.) Upper Basic or Pen-y-Gader Series	Pillow lavas (spilites) with tuff and chert bands . . . 300 ft
	(VI.) Llyn-y-Gader Mudstones and Ashes	Blue-grey mudstones with thin adinole-like bands and with massive ashes above and below. 450 ft
	(V.) Dark Mudstones	Frequently containing pisolitic iron-ore . . . . . 80 ft
	(IV.) Lower Basic or Llyn Gafr Series	Pillowy spilitic lavas with intercalated ashy and shaly bands, massive banded and agglomeratic ashes at the base . 1,500 ft
Lower Llanvirn	(III.) *Didymograptus bifidus* Beds	Dark slates with well-marked ash bands in the lower portion . 500 ft.
Arenig	(II.) Lower Acid or Mynydd Gader Series	Rhyolitic ashes with some slates above, rhyolitic lavas below 300 ft.
	(I.) Basement Beds .	Striped arenaceous flags and grits 100 ft.
	Unconformity	
Upper Cambrian	Tremadoc Beds	

Both acid and basic rocks occur as sills at numerous horizons. The basic rocks are diabases of various types, all with the felspars considerably albitised and usually with primary quartz. The acid rocks are soda-granophyres. The granophyre intrusions cut and are later than the basic intrusions, and locally hybrid rocks appear to have been formed along the junctions. No basic intrusions have been found above the Upper Basic Volcanic Series, and no acid intrusions above the Upper Acid

Series, and it is noteworthy that the granophyres appear to be closely related to the extrusive rhyolites among which they are intruded. This fixes an upper limit to the age of the diabases in this district.

The various beds strike more or less east to west, and dip steadily southwards at about 40° until the Talyllyn Mudstones are reached, when folding and rolling of the beds immediately begin. Two N.E.—S.W. shatter faults—the Dolgelley and Talyllyn faults—cause a certain amount of repetition, and give rise to the Dolgelley-Llyn Gwernon and to the Talyllyn Valleys, the former to the north and the latter to the south of the escarpment. A strike-fault between Mynydd Gader and Cader Idris cuts out the whole of the Bifidus Beds, bringing the Lower Acid and the Lower Basic Volcanic Series against one another. The intrusive rocks frequently cause local variations in the dip and strike.

All the softer strata are strongly cleaved, so that fossils are difficult to obtain. The slates within the Lower Acid Series have yielded a few extensiform graptolites, while from the Bifidus Beds the characteristic fossils were obtained at numerous localities. The *D. murchisoni* zone has not been recognised by the authors, its place presumably being occupied by a part of the Lower Basic Series. The dark mudstones among which the pisolitic iron-ore is developed have yielded rather obscure graptolites, which, however, indicate a fairly high horizon in the Llandeilo Series. The presence of *Amplexograptus arctus* and *Glyptograptus teretiusculus* var. *euglyphus* in the lowest beds of the Talyllyn Mudstones indicates a high horizon in the Glenkiln, or, in other words, a low horizon in the Caradocian, and suggests that the immediately underlying Upper Acid Series is at approximately the same horizon as the Snowdonian volcanic rocks of Conway. This youngest of the four volcanic series on Cader Idris is therefore considerably higher in the Ordovician than has been previously supposed. The position of the boundary between Caradocian and Llandeilian has not yet been established, owing to the unfossiliferous character of the blue-grey mudstones of Llyn-y-Gader and Llyn Cau.

One of the authors (A. H. Cox) is indebted to the Government Grant Committee of the Royal Society for a grant which has partially defrayed the expenses involved in the investigation. The area is being mapped on the 6-inch scale.

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4. *On the Underground Contours of the Barnsley Seam of Coal in the Yorkshire Coalfield.* By Professor W. G. Fearnsides, *M.A.*

In this paper the author presents a preliminary account of the results of his statistical analysis of about a hundred records of borings and sinkings which have proved the depth of the Barnsley Bed or its equivalents (the Gawthorpe, the Warren House Coals of Yorkshire, and the Top Hard Coal of Derbyshire) in Yorkshire. The majority of the records of borings and sinkings discussed have been collected by a committee of the 'Midland Institute of Mining, Civil and Mechanical Engineers,' published by that Institution in volume form in 1914, the sites at which the information was obtained being plotted on a half-inch map. The depths to the coal have been corrected for the height of the surface location above sea-level, and, after the manner of Dr. Gibson's map (Plate 1) in the 'Geological Survey Memoir on the Concealed Coalfield,' contour lines have been drawn among the spot-levels so obtained. Other contour lines similarly obtained from the records of borings which have passed through Permian strata show the character of the surface of the Coal Measures where they underlie the Permian strata.

In drawing the contour lines no attempt has been made to distinguish between those changes of level in the seam between neighbouring pits which are due to faulting and those due to the folding of the strata. Since, however, over most of the coalfield the faults tend to nullify the change of level which the dip has accomplished, it is maintained by the author that to plot contours which show the average rate of change of level is a statistical process which can be demonstrated as approximating to truth.

(1) From an analysis of the results as plotted it appears that the underground contours in the Barnsley Bed (strike lines) in Yorkshire in detail generally range either N.E.–S.W. or N.W.–S.E., and that within the area under which the Barnsley Bed has actually been proved by working it is difficult to find either a N.–S. or an E.–W. strike constant over more than a few miles

of country. This circumstance, if general over the coalfield, would seem to demand some revision of current views respecting the origin and structure of the Pennine Chain.[1]

(2) The greatest structural division of the coalfield 'basin' is by the equivalent of a N.E.-S.W. anticline of which the southern limb is along the line of the Don faults from Sheffield by Rotherham and Conisborough to Doncaster. North of this line there is some evidence for the existence of a syncline with its axis central near Frickley. In ground from which the Permian rocks have been denuded, the coal attains a depth exceeding 1,800 feet below sea-level. The general line of this northern trough follows a N.W.-S.E. trend from Wakefield to South Kirkby, whence, displaced perhaps by the Don anticline, it bends somewhat eastward through Bulcroft. South of the Don a wider trough, also trending N.W.-S.E. through Yorkshire Main Colliery (Edlington and Bawtry), carries the Barnsley bed (at Rossington) below 2,600 feet.

(3) The inclination of the Barnsley Bed is at its steepest near the outcrop, and, after the manner of gentle folds, the measures flatten out when the centre line of the syncline is approached. There is no evidence to suggest any general eastward rise of the Barnsley Seam within the area plotted on the map. (The eastern boundary of the map is through Thorne and Retford.)

(4) By the plotting of the contour lines on Bartholomew's layer-coloured half-inch contour map the interdependence of underground structure and topographical relief in the area of the exposed coalfield has been well brought out. Over the whole coalfield most of the ridges are of escarpment form and elongate along the line of strike; but from the map it becomes evident that, wherever the strike of the Barnsley Bed shows a change of direction, there the escarpment ridges are found upstanding above their average height, and this whether they form the arches or lie in the troughs of the folds.

From his experience of the application of the contour method to the study of the tectonics of the Barnsley Bed, the author suggests that the method is of peculiar usefulness in coalfield work. He offers this preliminary account of the results of his work in Yorkshire in the hope that workers on the western side of the Pennines may take up the method and use it in the further investigation of the many and difficult problems of geological structure presented by the 'Back-bone of England.'

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5. *Sixth Report on Excavations among the Cambrian Rocks of Comley, Shropshire.* *By* E. S. Cobbold.—See Reports, p. 117.

FRIDAY, SEPTEMBER 10.

The following Papers and Reports were read :—

1. *On the Restoration of certain Fossils by Serial Sections.* *By* Professor W. J. Sollas, *F.R.S.*

Examples of fossils reconstructed from serial sections were exhibited. They include a graptolite, *Prionograptus*; a primitive fish, *Palæospondylus*; the skull of a reptile from the Karoo, *Dicynodon*; and the skull of another reptile,

[1] These views were admirably expressed by Prof. E. Hull, who in advocating them in 1868 succinctly remarked (*Q.J.G.S.* 1869, p. 331): 'Immediately upon the close of the Carboniferous period the northern limits of the Yorkshire and Lancashire coalfields were determined by the upheaval and denudation of the beds along east and west lines, while the coalfields themselves remained in their original continuity across the region now formed of the Pennine hills from Skipton southwards, and that at the close of the Permian period these coalfields were dissevered by the uprising of the area now formed of the Pennine Range by lines of upheaval ranging from north to south.'

Ichthyosaurus communis, from the Lower Lias of Lyme Regis. The last-named, 520 mm. in length, had been studied in 520 sections taken at equal intervals apart, which revealed in remarkable detail the internal structure with a completeness hitherto unknown.

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2. *Vertebrate Life Zones in the Permo-Trias.* *By* D. M. S. Watson.

3. *The Corrosive Action of certain Brines in Manitoba.*
By Professor R. C. Wallace, *M.A., Ph.D., D.Sc.*

Brine springs issue from Middle and Upper Devonian limestones and dolomites at the foot of the Manitoban escarpment. At least eighty brine areas are known, with a total flow—during the dry season—of approximately 500 gallons per minute. The water circulates in the Dakota Sandstone, the basal member of the Cretaceous series, and extends laterally into the Devonian calciferous formations, from which it leaches sodium chloride, disseminated through certain dolomite horizons. The composition of the brines, expressed in percentages of total solids, is very similar to that of sea-water. It is a somewhat purer solution of sodium chloride, and also a more concentrated solution, than sea-water, the percentage salinity being 5—7 (sea-water 3·5).

The salt-flats where the springs reach the surface are devoid of vegetation, and studded with ice-carried boulders. These are representative of the pre-Cambrian igneous series of North-Central Canada—granites, gneisses, and epidiorites. They have suffered intense chemical disintegration, large boulders having been reduced to half their original size. Different minerals have been affected to different extents, but not even quartz or garnet has escaped corrosion. Ferromagnesians have been most intensely affected; and gneissose structures, hardly noticeable on unweathered surfaces, stand clearly revealed The striking difference between the action of these brines and that of sea-water calls for explanation

Thin crusts of salt gather, during the summer months, on the flats and around the boulders. The salt is somewhat deliquescent; and thin films of brine are drawn, by surface tension, over the surface of the boulders. Water in contact with the atmosphere is a powerful disintegrant. Alkalies are removed as chlorides or carbonates, and silica and alumina are precipitated as gels, separately or in combination. The gels exercise selective adsorption on the salts of the brine, alkali being taken up and the brine being left richer in the acid radicals. The brine is thereby rendered a more active disintegrating agent, and the process goes on continuously. The function of the dissolved salts is considered to be twofold: (1) they provide a thin film of liquid in contact with atmospheric oxygen; (2) owing to partial adsorption by colloids, they provide an acid residual solution, which is a powerful corrosive agent.

The evidences of the corrosive action of sea-water on beach boulders are, no doubt, obscured by mechanical attrition due to wave action. Such corrosion cannot, however, be compared in intensity with that of the brines. Boulders between high- and low-water mark are alternately submerged and dry to the base—a state of affairs inimical to the persistence of thin films of liquid on the surface of the boulders. The initial conditions are consequently wanting; and the relative immunity of beach boulders from chemical corrosion is due, not to any inability of sea-water to act as a corrosive, but to the absence of favourable conditions for the activity of the solution.

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4. *The Carboniferous Limestone Zones of N.E. Lancashire.*
By Albert Wilmore, *D.Sc.*

The sequence is well seen in the neighbourhood of Clitheroe, where numerous quarries have been opened up. The lowest beds exposed are near Chatburn mill, and are dark, thinly-bedded limestones with calcareous shale partings. Fossils are very scarce. There is a great thickness of these almost unfossiliferous beds, the top parts of which are dolomitic.

Bold Venture Quarry, Horrocksford Quarry, and several other exposures show beds in probably Lower C. with numerous small Zaphrentids (chiefly *Zaphrentis Omaliusi*, with the variety *ambigua* of Mr. R. G. Carruthers very common). Higher parts of these beds contain *Caninia cylindrica*, which has been found at Brungerly Bridge, in Bold Venture Quarry, at Pimlico, and at Downham. This species is not so common or well-developed as in beds farther east, towards Hellifield and district. Among the brachiopods are *Chonetes comoides*, *Orthotetes crenistria*, &c. Large gasteropods such as *Euomphalus pentangulatus* and *Bellerophon cornuarietis* are common. *Conocardium hibernicum* is a characteristic lamellibranch.

Above these beds come the lowest beds with *Productus sub-lævis*, and the Knoll beds of Coplaw, lower part of Worsaw, &c. Here are the typical C. knolls with numerous brachiopods, the gasteropods mentioned above, but few corals. *Amplexus coralloides* is, however, common and *Michelinia* sp.

Above these are well-bedded crinoidal limestones, leading up to the probably C.-S. knolls of Salt Hill, Bellman Park, Worsaw, &c. These beds contain a rich brachiopod fauna, quite distinct, however, from that of Elbolton. Whilst *Productus pustulosus*, *Pr. semireticularis*, *Spirifer striatus*, &c., are quite common, one never finds *Pr. striatus*, *Pr. martini* and other *D.* forms so common in those eastern knolls.

A fairly rich coral fauna has lately been discovered in these C.-S. or S. knolls; it has not yet been worked out, however. There is probably an unconformity at this level, and then there succeeds a great thickness of shales with limestones, with few fossils. These would appear to be on the same horizon as the richly fossiliferous beds of Elbolton. Above these shales with limestones come the Pendleside limestones, black limestones with cherts, and with irregular bands of more fossiliferous limestone. The Ravensholme limestone appears to be similar and to contain some of the same fauna as the highest limestone at Cracoe and the limestone of the railway quarry at Rylstone described by the writer.

The Sabden shales succeed these beds, and lead up to the Millstone Grit series. A map was exhibited on which some of these generalisations were shown.

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5. *A Brief Criticism of the Fauna of the Limestone Beds at Treak Cliff and Peakshill, Castleton, Derbyshire.* By HENRY DAY, *M.Sc.*

The author put forward some observations on a collection of some three hundred species of Carboniferous Limestone fossils from the localities Treak Cliff and Peakshill, Castleton, and embracing about one hundred species of brachiopods and corals. The beds at both places may be referred to the 'brachiopod beds' of Sibly ('Q.J.G.S. 1908'), and what are allocated by him to sub-zone D_2—the Lonsdalia sub-zone. The present list of species presents some features of considerable interest bearing on the value of certain types as zonal indices. Reference is made to Vaughan's paper on the Bristol area, where it is indicated that amongst the brachiopod groups confined to the Tournaisian in that area are the following: *Productus cf. Martini*; *Leptena analoga*; *Schizophoria resupinata*; *Rhipidomella aff. Michelini*; *Spiriferina octoplicata*; *Syringothyris cuspidata*. Two of these, it is noted, *Spiriferina octoplicata* and *Schizophoria resupinata*, are sub-zonal indices, and each with its maximum in its sub-zone. The list of Castleton forms from well up in D, now presented, includes all the above-mentioned brachiopod groups. *Syringothyris cuspidata* and *Spiriferina octoplicata* are fairly abundant at both Treak Cliff and Peakshill, *Schizophoria resupinata* is extremely abundant at both places, *Leptena analoga* is abundant, whilst *Productus cf. Martini* and *Rhipidomella Michelini* are rare.

Passing to the coral fauna, the genus Zaphrentis appears in the Castleton list, *i.e.*, one of the two genera of corals confined to the Tournaisian in the Bristol area and not extending into the Viséan. The genus, though not very abundant, is represented by several species. In addition, the genera Michelinia and Amplexus, characteristic of the Upper Tournaisian of Bristol, but possibly extending into the base of the Viséan, are cited in the Castleton list, *Michelinia*

glomerata being fairly abundant at Peakshill, and *Amplexus coralloides* is found at Treak Cliff, but is extremely rare.

These facts lead to a consideration as to how far the types mentioned are of value in zonal determinations. If any one of them, as recorded from Castleton, be regarded as representing exactly the same form as that recorded from the Bristol area, then its value as one of a number of index fossils of a zone becomes negligible. Examples are cited in the cases of *Spiriferina octoplicata* and *Schizophoria resupinata*. If the Castleton forms of D_2 horizon agree in identity with the Bristol types of K_2 and Z_2 respectively, then these two types become worthless as sub-zonal indices. It was pointed out that, even allowing of the rather unlikely possibility that in all the cases cited the Castleton specimens represented mutational forms of the Bristol species, the real difficulty as to their zonal value is not overcome, since the line of demarcation between mutations is more or less arbitrary and there is still a considerable field of discussion as to what constitutes a 'mutation.'

It appears probable that any system of zonal indices can be of local value only, as for example in the application of the Bristol zonal indices within the Bristol area, and cannot be of any general application.

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6. *Shift of the Western Shore-Line in England and Wales during the Avonian Period.* By Arthur Vaughan, *M.A., D.Sc., F.G.S.*

[The terms employed are merely explanatory and are not defended as the best that could be chosen.]

Join Wales across St. George's Channel to Co. Wicklow so as to form an unbroken mass of land : this mass will be termed 'Wales.' The sea south of this mass will be termed the 'S W. Channel'; it is an extended and modified Severn Channel.

Join Lakeland, Isle of Man, and Co Down by a much indented shore-line : this is the northern shore of what will be termed the 'N W. Channel,' the southern shore of which is the north coast of 'Wales.'

The shore-line under investigation may be considered at any period of the Avonian to be that which delimits a broad central and projecting land-mass ('Wales'), and two more or less narrow branches of the sea ('N.W. Channel' and 'S W. Channel') above and below.

Explanation of Map.

A pattern indicates the date of the earliest (or latest) deposit at a particular point. In the 'N.W. Channel' the pattern indicates the date of the *earliest* Avonian deposit at the place.

In the 'S W. Channel' the pattern indicates the date of the *latest* Avonian deposit at the place.

Hence, shore-lines (continuous patterned-lines) on the *north* coast of 'Wales' indicate an *advance* of the sea on to the land; whereas, on the *south* coast of 'Wales' they indicate retreat of sea and expansion of land.

The Shore lines at successive Zonal Dates.

[For zones and evidence, consult Report, Brit. Assoc., Winnipeg, Section C, and the later research of several investigators.]

β —Lower Tournaisian.

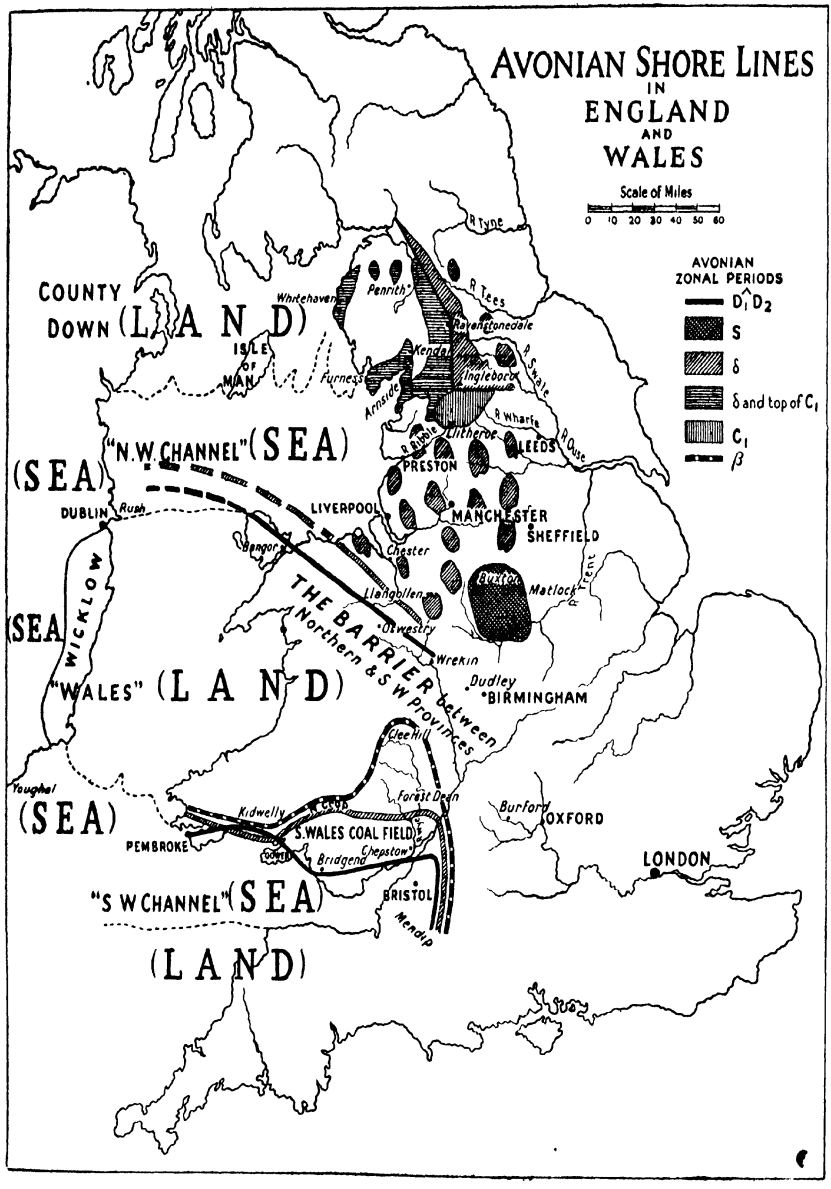
'N.W. Channel' scarcely, if at all, defined and confined to a shallow bay in Ireland : 'Wales' continues northwards in an unbroken mass.

'S.W. Channel' deeply deflected northward over Hereford to beyond Clee Hill : the most extensive encroachment of the 'S.W. Channel' upon the 'Wales' mass *during Avonian time.*

C_1—Top of Tournaisian.

The 'N.W. Channel' was initiated and Lakeland girdled by its earliest Avonian deposits.

The deepest C_1 deposits (which much resembled those of Rush) accumulated in the *Clitheroe* depression.



The marginal Tournaisian round Lakeland is often quite thin (and resembles that of Malahide).

[The sea did not cover the Ingleboro' area, N.W. of the faults. From the probable position of the coast line it seems that the basal Avonian beds of the I. of Man cannot be much later than C_1 or δ (and collections do not disprove this suggestion).]

δ —Basal Viséan—(C_2 + S_1 of old notation).

The 'N.W. Channel' overspread a wide area, including the Yoredale country N.W. of the Faults (Ingleboro', &c.) and the whole of South Lancashire; it commenced to climb the north coast of 'Wales,' reaching the neighbourhood of Llangollen.

The 'S.W. Channel' retreated from the Clee Hill embayment to such an extent that the new shore-line ran just north of the Forest of Dean.

S—Middle Viséan.

Deposition commenced in the 'N.W. Channel' over the Midland Area of Derbyshire, &c., and extended southward to Leicester (deduced from the shallow-water indications of the basal dolomites).

$\widehat{D_1D_2}$—Upper Viséan.

The 'N.W. Channel' climbed further up the north coast of 'Wales' so that the shore-line ran straight from Anglesey, through Oswestry, to the Wrekin.

The 'S.W. Channel' retreated still further southward, so that its shore-line ran just north of Bristol and continued in a straight line to Pembroke.

Notes.

The 'Barrier,' which formed the land-crest between the two channels during Viséan time, had a dominant trend from Anglesey to Dudley; it was never submerged throughout the Avonian period, so that the S.W. Province was only connected with the Northern and Midland Provinces round the Irish coast of 'Wales.'

The whole neck of land which contained the 'Barrier' and separated the two 'channels' shifted steadily southward as Viséan time proceeded, owing to the advance of the sea on the north of 'Wales' and its retreat on the south.

The remarkable similarity of the Viséan sequence in the N.W and S.W. Provinces (compare Shap or Arnside with Bristol or Mendip) indicates free communication of the two channels round the western or Irish front of 'Wales,' aided by great similarity of the northern margins of the 'N.W.' and 'S.W. Channels.'

The western or Irish coast of 'Wales' probably shifted but little during the period, for just N. of Dublin (Rush, Malahide, &c.) the sea remained persistently coastal (as shown by the conglomerates, dolomites, &c).

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7. *A Preliminary Note on the Glacial Geology of the Western Slopes of the Southern Pennines.* By Albert Jowett, *D.Sc., F.G.S.*

The area dealt with extends from Blackstone Edge southwards to the southern extremity of the Pennines.

No striated surfaces of solid rock have been discovered at high levels, and the two that have been recorded at Salford and Fallowfield serve only to indicate a general movement from N.W. to S.E. For more detailed information as to the movements of the ice-sheet, the only evidence is that afforded by the distribution of the drift at high-levels and by the systems of drainage along the edge of the ice. From this it may be inferred that the main directions of ice-movement about the time of the maximum extension of the ice-sheet were roughly towards the north-east in the Tame valley, the east in the Etherow valley, and the south-east and south-south-east in the Goyt valley and further south. These directions were much modified locally by the complicated configuration of the sub-glacial surface.

The first barrier of hills met with on approaching the Pennines from the South-Lancashire and Cheshire plain was almost everywhere overridden by ice, which left definite deposits of drift with foreign rocks at altitudes up to 1,360 feet, and scattered erratic boulders up to 1,400 feet. As this foreign drift penetrates further into the hills its maximum altitude falls steadily. It has only been traced across the main Pennine divide at the broad col (1,100 feet above O.D) south-east of Chapel-en-le-Frith.

Thick deposits of drift and big erratics are comparatively rarely met with at the extreme limit of the foreign drift, towards which the erratics generally

diminish in number and in size. Boulders of local rocks, often obviously transported and uplifted beyond their parent outcrops, become relatively more abundant towards the limit of the foreign drift, and generally form a spread of drift extending beyond it and passing insensibly into the driftless area.

Great lakes were held up by the ice-barrier some time after it commenced to retreat from the western slopes of the Pennines. During early stages in this retreat the drainage from the lakes in and north of the Etherow valley escaped northwards, and ultimately passed through the Walsden gap into the Calder. When the ice-barrier east of Manchester fell below 600 feet above O.D., this drainage followed the course of that south of the Etherow valley and escaped southwards.

The action of the ice-sheet with its associated streams of water, together with the marginal water derived from melting ice and draining from the region beyond the ice-sheet, assisted by the action of post-glacial streams, in depositing the original drift, in cutting new channels through rock and drift, and in resorting and redepositing the débris, seems quite sufficient to account for the complicated superficial deposits in this area.

No evidence has been found of more than one period of glaciation nor of any local glacier system. There are, however, curious corrie- or cirque-like features, *e.g.*, on Shelf Moor, Glossop. Moreover, although the Pennines are on the whole much lower north of the Etherow Basin than further south, the overflow-channels of glacier-lakes can be found at higher altitudes in the former than in the latter region. This is the reverse of what might be expected if the higher ground were ice-free. It may be, therefore, that at and near the time when the ice-sheet attained its maximum development, the snow-line actually descended below the altitude of the higher Pennine hills, and, without bringing about a definite local glaciation, temporarily filled the higher hollows with snow up to the general level of the ridge. Thus, instead of the margin of the ice-sheet at that stage melting away rapidly, melting might be considerably reduced and even temporarily suspended, and the ice-sheet reinforced by the local snow-fall. Such conditions would tend to depress the limit of distribution of erratics immediately west of the highest ground, but where an ice stream carrying erratics actually crossed the watershed, they might lead to the distribution of those erratics further and more widely than otherwise might have been possible.

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8. *Discussion on Radio-active Problems in Geology.*

(*a*) Professor Sir E. RUTHERFORD, *F.R.S.*, opened the Discussion.

(*b*) *Contribution to the Discussion on Radio-active Evidence of the Age of the Earth.* *By* ARTHUR HOLMES, *D.I.C., B.Sc.*

The radio-active methods of measuring geological time have given results which are consistent among themselves. The unavoidable discrepancies between the periods based on helium-ratios and those calculated from corresponding lead-ratios do not stand in need of reconciliation, and if they did the pleochroic-halo method is there to bridge the gap. On account of the leakage of helium, periods based on the accumulation of the latter are always smaller—invariably less than half—than those implied by the accumulation of lead. Consequently, the greatest age deduced from helium-ratios, 715,000,000 years for a sphene from the Lower Pre-Cambrian rocks of Ontario, Canada, is not likely to be more than half the true value. In keeping with this supposition, the greatest age yet determined by the lead-ratio method amounts to 1,500,000,000 years, this figure referring to zircons derived from the oldest granitic rocks of the Pre-Cambrian platform of Mozambique.

Supporting this result are the lead-ratios of the well-known radioactive minerals of the Middle Pre-Cambrian of Norway and Sweden. The ratios fall into two well-marked groups, which indicate ages of 1,000,000,000 and 1,200,000,000 years respectively. The lower figure is of special value, not only because of the consistent testimony of eleven minerals, but also because lead

which has been prepared from one of them has an atomic weight of 206·06 (Hönigschmid, 1914), a fact which ensures its radioactive origin.

Hitherto all time periods have been calculated on the assumption that the radioactive 'constants' of uranium and its daughter elements have not varied with time. Keeping this in mind, we may, I think, tentatively accept some period such as 1,500,000,000 years, as representing the time that has elapsed since the crystallisation of the oldest plutonic rocks of the earth's crust. The actual age of the earth must, of course, be greater even than this—on the assumption specified—for wherever geological evidence is clear, the oldest plutonic rocks are found to be intrusive into a pre-existing sedimentary or volcanic series.

Yet geological attempts to determine the age of the earth, founded on sedimentation and salt accumulation, point to considerably lower figures, say 100,000,000 to 400,000,000 years. Certainly the data on which the geological methods depend are of doubtful value; and the assumption of uniformity which underlies their interpretation is clearly far from being justified. Nevertheless, although the geological results are thus discredited at their source, they make it advisable to examine carefully the assumption of uniformity lying behind the radioactive figures.

The third method of determining geological time, that based on the now hypothetical cooling of the earth's 'crust,' would probably dissolve the controversy, if it did not, unfortunately, precipitate a fresh one. The new difficulty is that the traditional view of a surface originally molten, or practically so, is not altogether regarded with favour in the light of the planetesimal hypothesis. However, ignoring this for the moment, it is safe to say, with the existing distribution of uranium and thorium in the surface rocks, that our planet cannot have cooled down to its present condition (from a stage when the temperature near the surface was approximately 1,000° C.) in less than 1,600,000,000 or 1,700,000,000 years. These figures again imply that the rates of decay of the radioactive parent elements have not varied during the earth's history.

As Professor Joly has suggested, the discrepancy between the numerical results of the geological, and lead and helium methods would disappear, in favour of the former, if it could be shown that the rate of decay of uranium had decreased with the lapse of time. Reconciliation would then be effected from the fact that the present accumulation of lead in uranium minerals would have required a shorter period of time than could have been possible on the assumption of uniformity. However, an equally certain deduction is that during any given time in the past more heat of radioactive origin would have been generated in the rocks than the amount calculated on the basis of uniformity. As a result, the secular cooling of the earth would have been slowed down to such an extent that it would be either reversed, or so prolonged that the age would become ridiculously high. The only alternative to this *reductio ad absurdum* is to conclude that the earth never has been molten at or near the surface.

Although belief in an all-time solid earth does not of itself invalidate the highest figures based on lead-ratios and uniformity of decay, yet it is an assumption that must be granted before acceptance of a lower figure for the age of the earth becomes consistent. On the other hand, if geologists favour an earth initially molten near the surface, then the low figures afforded by the accumulation of salt and sediment must of necessity be rejected in favour of the higher results afforded by the accumulation of lead generated at a constant rate.

It should be observed, in passing, that the lead-ratio, quite apart from the age which it represents, is a factor of extreme value to the geologist. With its help the great granite intrusions of the Archæan platforms in various parts of the world may be correlated, and in other cases when suitable minerals are available for analysis, the period to which an igneous intrusion should be assigned may be determined approximately, even though field evidence is totally lacking.

Professor Soddy has suggested that the final product of the thorium series is probably an isotope of lead. This view is unsupported by mineralogical evidence. However, while the lead-ratios of minerals rich in thorium may be reliable, and may give just the same result as that of a contemporaneous uraninite, yet in the majority of examples they are remarkably variable. This fact, and the evidence of atomic weights, indicate that thorium tends to be accompanied by primary lead of the ordinary type, in much the same way,

perhaps, as zinc is commonly accompanied by cadmium. For these reasons I feel that the lead-ratios of thorium minerals, notably those of the thorites and thorianites of Ceylon, and the thorites of the Devonian pegmatites of southern Norway, should be altogether rejected for our purpose

At the present time, the radioactive problems which, for the geologist, are in most urgent need of solution are concerned with the possible dependence of the rate of decay of uranium on time, pressure, and temperature. In turn, the geological problem now most likely to throw light on the correct interpretation of lead-ratios is that of deciding whether or not the earth has ever been molten at or near the surface.

(c) *Contribution to Discussion on Radio-active Problems*
By Professor F. SODDY, *F.R.S.*

Professor SODDY hoped that geologists would not be in any immediate hurry to decide between the geological and radio-active estimates of the age of the earth Owing to the element of uncertainty about the initial stages of the disintegration and the long periods involved there was a great *terra incognita*, and the new theory of isotopes made it necessary to take into account many possibilities, some of them referred to by Professor Joly, not thought of a couple of years ago. In addition there was always the possibility that thorium might be a branch of the uranium family, in which case some of the arguments that had been used entirely fell to the ground While he saw no successful method at present of altering the *general order* of the radio-active estimate, he did not regard it as more than tentative, and there might well be unknown factors still to be discovered sufficiently important to bring the two methods into closer agreement.

9. *Twinning in Metallic Crystals.* *By* Professor C. A. EDWARDS

10. *The Isolation of the Directions-Image of a Mineral in a Rock-Slice*
By J. W. EVANS, *D.Sc., I.L.B.*

The author discussed the different methods by which the interference figures of a small mineral in a rock slice may be kept distinct from those of adjoining minerals He recommended two In one, which he believes to be new, a diaphragm with a small aperture is placed below the condenser, which is lowered till the image of the aperture appears in focus on the rock slice In some microscopes the iris diaphragm provided for the Becke method of determining the refractive index may be employed In others it is too near the condenser The aperture should be sufficiently large to illuminate the maximum area of the mineral under investigation, but no portion of the others. The directions image may then be observed in any of the usual ways. Unless the condenser and diaphragm revolve with the stage the aperture must be very carefully centred with the axis of rotation.

The other method was proposed by Becke in 1895, but is very little known. The diaphragm is placed in the focus of the eye-piece so as to shut out all except the mineral selected The Becke lens, or system of lenses resembling an eye-piece, is placed above the eye-piece, when the directions-image of the mineral will be seen without any admixture of light from its neighbours. This method has the advantage that the diaphragm is less highly magnified at the time of adjustment. When a rotating stage is employed, a very accurate centring of the nose-piece of the microscope is required, so that the coincidence of the object with the aperture may be maintained.

The common practice of placing a diaphragm for this purpose immediately below the Bertrand lens rests on no scientific basis, and is not effective in shutting out the light of minerals other than that which is being studied.

11. *The Micro-Structure of Coal.* By Dr. G. Hickling.

The author stated that his chief aim was to establish the thesis that coal is essentially a 'replacement' deposit, consisting of an originally peat-like mass of vegetable débris, in which the substance of the component tissues has been largely or wholly replaced by the liquid decomposition-products of other vegetation. This conclusion is primarily based on the examination of typical 'bituminous' coals, in which nearly the whole substance of the coal is transparent and orange- or brown-coloured in good sections. In this material vegetable structure is often shown, sometimes in surprising perfection, with the cell-walls uncrushed. The cell-cavities in such tissues are filled with the same material which forms the main mass of the coal, and since the amount of this material must be several times greater than the original (dehydrated) organic content of the cell, there can be no doubt that it is material secondarily introduced. Further, since it pervades extensive masses of tissue with the cell-walls intact, there can be no question as to the conclusion that it was introduced as a fluid penetrating the cell-membranes. The only *visible* differentiation in the substance of such coal is that due to variation in depth of colour. In this way 'cell-walls' are distinguished from 'cell-contents,' but commonly, as the tissue is followed in one direction or another, the differentiation of walls and contents decreases and finally vanishes, whence the tissue merges in an apparently structureless mass. It appears probable that nearly the whole of such a coal consists of 'replaced tissues,' in only a small proportion of which there is sufficient differentiation to render cellular structure visible.

The depth of colour of the coal substance was shown to increase with increasing carbon percentage, as indicated by the streak, which varies from pale brown in coals with 70 per cent carbon to black in those with 95 per cent. Hence it is increasingly difficult to prepare transparent sections as the carbon-content rises. Great variation, however, is found in the degree of uniformity or otherwise of the coal-substance. Typical 'bituminous' coals tend to be homogeneous, while cannels and cannéloid coals are characterised by the association of an opaque or very dark-coloured 'base' (? of high carbon-content) with abundant pale-coloured bodies, usually spores or the 'algæ' of Bertrand and Renault (? of low carbon-content).

The recognisable plant-structures present in coal include cortical tissues, wood, leaves, isolated cuticles and spore-coats. Unbroken pieces of tissue of considerable size are scarce, a minutely fragmentary condition being general. The individual fragments are almost always lenticular, from the effect of compression combined with an always present flow-structure. No indication has been found to show that high-carbon coals differ in original vegetable constituents from low carbon coals.

True woody tissues are commonly preserved as 'mother-of coal,' in which the lumen of the vessels is still empty or filled with secondary mineral matter, the walls being converted into opaque material. No other type of tissue has been certainly found to exhibit this type of preservation.

Evidence was brought forward to show that, whatever may be the true nature of the 'algæ' described by Bertrand and Renault in cannel and similar coals, they cannot in all cases be regarded as spores, as some recent authors have suggested.

12. *On the Economic Mineral Products of Damaraland, S.W. Africa.* By Thomas Crook.

13. *Report on the Preparation of a List of Characteristic Fossils.*

See Reports, p. 116.

14. *Report on the Nomenclature of the Carboniferous, etc., Rocks of the Southern Hemisphere.*—See Reports, p. 263.

15. *Report on the Preparation of a List of Stratigraphical Names.* See Reports, p. 123.

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16. *Report on Critical Sections in Lower Palæozoic Rocks of England and Wales.*—See Reports, p. 117.

17. *Report on the Old Red Sandstone Rocks of Kiltorcan, Ireland.* See Reports, 117.

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION:—PROFESSOR E. A. MINCHIN, M.A., HON. PH.D., F.R.S.

WEDNESDAY, SEPTEMBER 8.

The President's Address was read in his absence, as follows:—

The Evolution of the Cell.

WHEN addressing an audience of biologists it would be superfluous to insist upon the importance of the study of the cell and its activities. It is now recognised almost universally that the minute corpuscles known by the somewhat unsuitable term 'cells' are the vital units of which the bodies of animals and plants are built up, and that all distinctive vital processes—metabolism, growth and reproduction, sexual phenomena and heredity—reduce themselves ultimately to activities taking place in, and carried on by, the individual cells which build up the body as a whole. Each cell must be regarded as a living, individual organism which, however much it may be specialised for some particular function or form of vital activity, is capable of maintaining its life and existence in a suitable environment by carrying on all the necessary processes of metabolism which are the essential and distinctive characteristics of living beings. In the case of cells composing the complex body of the higher animals and plants the cells are mutually interdependent, and, with the exception of the mature germ-cells, cannot maintain their existence apart from their fellows; that is to say, the only natural[1] environment suitable for their continued existence is the complex body or cell-commonwealth of which they form an integral part. But in the simplest forms of life the whole body of the living individual may reach no higher degree of complexity than the single cell, which is then seen as an organism physiologically complete in every respect, living a free and independent life in Nature and competing with other organisms of all kinds, simple or complex, in the universal struggle for existence amongst living beings. This statement of the 'cell-theory' is that with which, I believe, the majority of modern biologists would agree; not without, however, some dissentients, amongst whom I personally am not to be numbered.[2]

The fundamental importance of the cell as a complete living organism, whether maintaining itself singly and independently or in union with other similar but individually specialised units, has made it the object of intensive and concentrated study, not only by those who group themselves according to their special points of view as zoologists, botanists, physiologists, &c., but also by a class of investigators who take the cell itself as the subject of a branch

[1] It is not necessary to do more than refer here to the investigations that have been carried on in recent years with regard to the viability and multiplication of tissue-cells removed from the body in artificial culture-media. These experiments afford strong support to the view that the cell is to be regarded primarily as an independent living organism.

[2] See Appendix A.

of biological investigation termed cytology, which deals with cells in a general manner independently of their provenance, whether animal or vegetable. Some knowledge of the cell and its activities is necessary at the present time for every one concerned with the study of living things, whether that study is pursued for its own sake and with disinterested objects, or with the intention of applying scientific principles to practical aims, as in medicine or agriculture. One might have expected, therefore, that at least some elementary understanding of the nature and significance of the cell, and the importance of cellular activities in the study of life and living things, would have formed at the present time an indispensable part of the stock of knowledge acquired by all intelligent persons who are ranked as 'educated' in popular estimation. Unfortunately this is so far from being the case that it is practically impossible, in this country at least, to find anyone amongst the educated classes to whom the words 'cell' and 'cytology' convey any meaning at all, except amongst those who have interested themselves specially in some branch of biology. Consequently, any discussion concerning the cell, although it may deal with the most elementary processes of life and the fundamental activities and peculiarities of living beings, ranks in popular estimation as dealing with some abstruse and recondite subject quite remote from ordinary life and of interest only to biological specialists. It must, however, be pointed out that the general state of ignorance concerning these matters is doubtless in great part due to the fact that an objective acquaintance with cells cannot be obtained without the use of expensive and delicate optical instruments.

I propose in this address to deal with an aspect of cytology which appears to me not to have received as yet the attention which it deserves, namely, the evolution of the cell itself and of its complex organisation as revealed by the investigation of cytologists. Up to the present time the labours of professed cytologists have been directed almost entirely towards the study of the cell in its most perfect form as it occurs in the Metazoa and the higher plants. Many cytologists appear indeed to regard the cell, as they know it in the Metazoa and Metaphyta, as the beginning of all things, the primordial unit in the evolution of living beings.[3] For my part I would as soon postulate the special creation of man as believe that the Metazoan cell, with its elaborate organisation and its extraordinarily perfected method of nuclear division by karyokinesis, represents the starting-point of the evolution of life. So long, however, as the attention of cytologists is confined to the study of the cells building up the bodies of the higher animals and plants, they are not brought face to face with the stages of evolution of the cell, but are confronted only with the cell as a finished and perfected product of evolution, that is to say, with cells which, although they may show infinite variation in subordinate points of structure and activity, are nevertheless so fundamentally of one type that their plan of structure and mode of reproduction by division can be described in general terms once and for all in the first chapter of a biological text-book or in the opening lecture of a course of elementary biology.

One of the most striking features of the general trend of biological investigation during the last two decades has been the attention paid to the Protista, that vast assemblage of living beings invisible, with few exceptions, to the unassisted human vision and in some cases minute beyond the range of the most powerful microscopes of to-day. The study of the Protista has received in recent years a great stimulus from the discovery of the importance of some of the parasitic forms as invaders of the bodies of men and animals and causers of diseases often of a deadly nature; it has, however, yielded at the same time results of the utmost importance for general scientific knowledge and theory. The morphological characteristic of the Protista, speaking generally, is that the body of the individual does not attain to a higher degree of

[3] For example, my friend Dr. C. E. Walker, in an article in *Science Progress* (vol. vii. p. 639), after stating that 'The unit of living matter, so far as we know, is the cell,' proceeds to deal with 'that form in which it is found in the multicellular and the majority of unicellular organisms, both animal and vegetable' and then describes the typical cell of the cytologist, with nucleus, cytoplasm, centrosome, chrondriosomes, and reproduction with fully developed karyokinesis.

organisation than that of the single cell. The exploitation, if I may use the term, of the Protista, though still in its initial stages, has already shown that it is amongst these organisms that we have to seek for the forms which indicate the evolution of the cell, both those lines of descent which lead on to the cell as seen in the Metazoa and Metaphyta, as well as other lines leading in directions altogether divergent from the typical cell of the text-book We find in the Protista every possible condition of structural differentiation and elaboration, from cells as highly organised as those of Metazoa or even, in some cases, much more so, back to types of structure to which the term cell can only be applied by stretching its meaning to the breaking-point. Already one generalisation of cytologists has been torpedoed by the study of the Protista The dictum 'Omnis nucleus e nucleo' is perfectly valid as long as it is restricted to the cells of Metazoa and Metaphyta, to the material, that is to say, to which the professed cytologist usually confines his observations.[4] But in the Protista it is now well established that nuclei can arise *de novo*, not from pre-existing nuclei but from the extranuclear chromatin for which Hertwig first coined the term 'chromidia'

It is clear, therefore, that the results already gained from the study of the Protista have brought about a new situation which must be faced frankly and boldly. It is impossible any longer to regard the cell as seen in the Metazoa and as defined in the text-books as the starting-point of organic evolution. It must be recognised that this type of cell has a long history of evolution behind it, which must be traced out, so far as the data permit. The construction of phylogenies and evolutionary series is of course purely speculative, since these theories relate to events which have taken place in a remote past, and which can only be inferred dimly and vaguely from such fragments of wreckage as are to be found stranded on the sands of the time in which we live. Many important stages of evolution may be totally submerged and no longer available for study and consideration. The extent to which such speculations will carry conviction to a reasonable mind will depend entirely on the stores of data that can be collected and which must be the last appeal for the cogency of all arguments and judgments The study of the Protista is as yet in its infancy; groups have been recognised and have received ponderous designations although their very existence is yet in doubt, as in the case of the so-called Chlamydozoa; and our knowledge of the affinities and mutual relationships of the groups is still very imperfect. All attempts, therefore, to trace the evolution of the Protista must be considered as purely tentative at present. If I venture upon any such attempt, it is to be regarded as indicating a firm belief on my part that the evolution of the cell has taken place amongst the Protista, and that its stages can be traced there, rather than as a dogmatic statement that the evolution has taken place in just the manner which seems to me most probable. When we reflect on the irreconcilable differences of opinion amongst zoologists with regard to the origin and ancestry of vertebrates, for example, we may well be cautious in accepting pedigrees in Protista.

Before, however, I can proceed to deal with my main subject, it is absolutely necessary that I should define clearly the sense in which I propose to use certain terms, more especially the words 'cell,' 'nucleus,' 'chromatin,' 'protoplasm,' and 'cytoplasm.' Unless I do so my position is certain to be misunderstood, as, indeed, it has been already by some of my critics.

The term cell was applied originally by botanists to the single chambers or units of the honeycombed structure seen in the tissues of plants. The application of the term to such structures is perfectly natural and intelligible, since each such cell in its typical form is actually a closed space limited by firm

[4] Vejdovský (*Zum Problem der Vererbungstrager*, Prag, 1911 1912, p. 120) has already maintained, for the cells of Metazoa, that Fleming's aphorism 'Omnis nucleus e nucleo' should be changed to 'Omnis nucleus e chromosomatis' [*sic*], on the ground that the nucleus, as such, is not an original cell-component 'but is produced secondarily from the chromosomes of the mother-cell' If this is true, there is but little difference in detail, and none in principle, between the formation of 'secondary' nuclei from chromidia and the reconstruction of a daughter-nucleus from chromosomes in the most perfected form of karyokinesis.

walls, and containing a relatively large quantity of fluid cell-sap and a small quantity of the slimy protoplasmic substance. When these structures were first discovered, the limiting membrane or wall of the cell was regarded as essential, and less importance was attached to its contents. With increased knowledge, however, and especially when animal tissues came to be studied, it became apparent that the cell-wall, like the fluid cell-sap, was a secondary product, and that the essential and primary part of the cell was the viscid protoplasmic substance, in which a peculiar body, the 'nucleus' or kernel, was found to be universally present. Consequently the application and meaning of the term cell had to undergo an entire change, and it was defined as a small mass or corpuscle of the living substance, protoplasm, containing at least one nucleus. To these essential constituents other structures, such as a limiting membrane or cell-wall, and internal spaces—vacuoles—filled with watery fluid, might be added as products of the secretory or formative activity of the living substance; but such structures were no longer regarded as essential to the definition of the cell, since in many cases they are not present. It is to be regretted in some respects that with this changed point of view the term 'cell,' used originally under a misapprehension, was not replaced by some other term of which the ordinary significance would have been more applicable to the body denoted by it.[5]

The chief point that I wish to establish, however, is that the term cell was applied originally to the protoplasmic corpuscles building up the bodies of the Metazoa and Metaphyta, each such corpuscle consisting of a minute individualised mass of the living substance and containing a nucleus. Hence a complete cell is made up of two principal parts or regions, the nucleus and the remainder of the protoplasmic body, termed the cytoplasm. By some authors the term protoplasm is restricted to the cytoplasmic portion of the cell, and protoplasm is then contrasted with nucleus; but it is more convenient to consider the whole cell as composed of protoplasm divided into two regions, nucleus and cytoplasm.

We come now to the consideration of the body termed the nucleus, which undoubtedly possesses an importance in the life and functions of the cell far greater than would be inferred from the name given to it. A nucleus, as seen in its typical form, has a limiting membrane enclosing a framework composed of a substance termed 'linin.' The framework has the form of a network, which is probably to be interpreted, primitively at least, as the optical expression of an alveolar structure similar to that seen also in the cytoplasm, but of coarser texture, and the apparent 'threads' of the linin-framework may then be the optical sections of the partitions between neighbouring alveoli. Such an interpretation does not exclude the possibility of the formation of real threads or fibres in the framework in certain cases or during particular periods of nuclear activity; just as fibrous structures may arise in the alveolar cytoplasm also. The cavities of the framework contain a watery fluid or nuclear sap, probably of the same nature as the fluid enchylema or cell-sap contained in the alveolar framework of the cytoplasm. At the nodes of the alveolar framework are lodged grains or masses of *chromatin*, a substance which must engage our most particular attention, since it is the essential constituent of the nucleus, universally present in all nuclei, whether of the simplest or of the most complex types. In addition to the chromatin-grains, which are distributed in various ways over the linin-framework, there are to be found usually one or more masses termed nucleoli, composed of a material which differs from chromatin in its reactions and has been termed plastin.

In the foregoing paragraph I have described in general terms the typical nucleus of the text-books, as found commonly in the cells that build up the bodies of ordinary animals and plants. The minutiæ of the details of structure and arrangement of the constituent parts may vary infinitely, but the type remains fairly constant. When we come, however, to the nuclei of the Protista, such pronounced modifications and variations of the type are met with

[5] 'Nothing could be less appropriate than to call such a body a "cell"; yet the word has become so firmly established that every effort to replace it by a better has failed, and it probably must be accepted as part of the established nomenclature of science.'—E. B. Wilson, *The Cell*, p. 19.

that a description in general terms is no longer possible. I shall deal with some of these types later in my attempts to reconstruct the evolution and phylogeny of the cell. I will draw attention now only to a few salient points. In the Protist cell the chromatin is not necessarily confined to the nucleus, but may occur also as extranuclear grains and fragments termed chromidia, scattered through the protoplasmic body; and the chromatin may be found only in the chromidial condition, a definite nucleus being temporarily or permanently absent. Further, when a true nucleus is present in the Protist body, it seldom contains a nucleolus of the same type as that seen in the nuclei of tissue-cells, that is to say, a mass of pure plastin, but in its place is found usually a conspicuous body which shows reactions agreeing more or less closely with those of chromatin and which consists of a plastin-basis more or less densely impregnated with chromatin. Such a body is termed a karyosome (or chromatin-nucleolus) to distinguish it from the true nucleoli (plastin-nucleoli) characteristic of tissue-cells. According as the plastin or the chromatin predominates in the composition of a karyosome, its reactions may resemble more nearly those of a true nucleolus in the one case, or those of chromatin in the other. The so-called karyosomatic type of nucleus is very common in the Protista, but by no means of invariable occurrence; in many cases the nucleus consists of a clump of small grains of chromatin, with no distinct karyosome, or with a karyosome which consists mainly of plastin. Thus two extreme types of nuclear structure can be distinguished and may be termed provisionally the karyosomatic type and the granular type, ignoring for the sake of convenience in nomenclature the types of structure transitional between the two; as, for example, types in which a distinct karyosome is seen together with more or fewer peripherally arranged grains of chromatin.

In either the karyosomatic or the granular type of Protist nucleus we may find great simplification of the complex type of nuclear structure seen in the tissue-cells of animals and plants. Thus in the first place a distinct nuclear membrane may be entirely absent and the chromatin-elements, whether occurring in the form of a compact karyosome or of a clump of grains, are lodged simply in a vacuole in the cytoplasm, that is to say in a cavity containing a watery fluid of nuclear sap in which the mass or masses of chromatin are suspended. It is a moot point, to which I shall return again, whether in nuclei of this simple type the linin-framework may sometimes be absent altogether, or whether it is invariably present in at least a rudimentary form, appearing as delicate threads (in optical section) extending from the chromatin-masses to the limiting wall of the nuclear vacuole, or between the grains of chromatin themselves. When such a framework can be detected, the nucleus acquires the appearance, in preserved preparations at least, of possessing a definite structure and is often termed a resting nucleus; many observations have shown, however, that the nucleus during life is undergoing continual internal movements and re-arrangements of its parts and is by no means at rest. The linin-framework cannot, therefore, be regarded in any way as a rigid skeleton, but must be interpreted as an alveolar framework similar to that of the general protoplasm and equally liable to movement, displacement, and change.

From this survey, necessarily most brief and superficial, of the manner in which the nuclei of Protists may vary from the type of nucleus described in the text-books, it is at once evident that the essential part of the nucleus is the chromatin, and that the other structural constituents of the nucleus, namely, membrane, framework, and plastin or nucleolar bodies, are to be regarded as accessory components built up round, or added to, the primary nuclear material, the chromatin. Even with regard to the nuclei of Metazoa it is maintained by Vejdovský that at each cell-generation the entire nucleus of the daughter-cell is produced from the chromosomes alone of the mother cell.[6] The simplest body which can be recognised as a nucleus, distinct from the chromidia scat-

[6] Walker, on the other hand, considers that 'it seems quite possible that the chromatin is merely a secretion of the linin.' (*Science Progress*, vol. vii. p. 641.) I doubt whether there are many cytologists who would admit this possibility, and I think that very few protistologists would assent to any such notion, since in the nuclei of Protista the linin-framework is in many cases very little in evidence, if present at all.

tered without order or arrangement throughout the protoplasmic body, is a mass of chromatin or a clump of chromatin-grains supported on a framework and lodged in a special vacuole in the cytoplasm. The complexity seen in the most perfect type of nucleus takes origin by progressive elaborations of, and additions to, a structure of this simple and primitive type.

This brings me to a point which I wish to emphasise most strongly, namely, that the conception of a true cell-nucleus is essentially a structural conception. A nucleus is not merely an aggregation of chromatin; it is not simply a central core of some chemical substance or material differing in nature from the remainder of the protoplasm. As Dobell has well expressed it, a pound of chromatin would not make a nucleus. The concepts 'nucleus' and 'chromatin' differ as do those of 'table' and 'wood.' Although chromatin is the one universal and necessary constituent entering into the composition of the cell-nucleus, a simple mass of chromatin is not a nucleus.[7] A true nucleus is a cell-organ, of greater or less structural complexity, which has been elaborated progressively in the course of the evolution of the cell; it is as much an organ of the cell as the brain is an organ of the human body. As a definite cell-organ, it performs in the life and economy of the cell definite functions, which it is the province of the cytologist to observe and to study, and if possible to elucidate and explain. As an organ of the cell, however, it has no homologue or analogue in the body of the multicellular animals or plants; there is no organ of the human body, taken as a whole, similar or comparable to the nucleus of the cell. Consequently, in studying the functions of the nucleus the human cytologist finds himself in the same difficult position that an intelligent living being lacking the sense of sight would be when trying to discover the function of visual organs in other organisms possessing that sense. There is no organ of known and understood functions with which the cytologist can compare the cell-nucleus directly.

The foregoing brief consideration of the nucleus leads me now to discuss in more detail the nature and properties of the essential nuclear substance, the so-called chromatin. To define, or characterise adequately, this substance is a difficult task. The name chromatin is derived from the fact that this substance has a peculiar affinity for certain dyes or stains, so that when a cell is treated with the appropriate colouring reagents—with so-called nuclear stains—the chromatin in the nucleus stands out sharply, by reason of being coloured in a different manner from the rest of the cell. In consequence, the statement is frequently made, in a loose manner and without reflection, that chromatin is recognised by its staining reactions, but in reality this is far from being true. When a preparation of an ordinary cell is made by the methods of technique commonly in use, the chromatin is recognised and identified by its position in a definite body with characteristic structure and relations to the cell as a whole, namely the nucleus, and this is equally true whether the chromatin has been stained or not. When the cell has been stained with one of the dyes ordinarily in use for colouring the chromatin, there are often seen in the cytoplasm grains that are coloured in exactly the same manner as the chromatin-grains lodged in the nucleus. Is an extranuclear grain which stains like chromatin to be identified, *ipso facto*, as chromatin? By no means; it may or it may not be chromatin. Simple inspection of a stained preparation is altogether inadequate to determine whether such a body is or is not chromatin. Any so-called chromatin-stain colours many bodies which may occur in a cell besides the chromatin, and it may be necessary to try a great many

[7] Professor Armstrong writes: 'Every organism must possess some kind of nucleus, visible or invisible; some formative centre round which the various templates assemble that are active in directing the growth of the organism.' (*Science Progress*, vol. vii. p. 328.) I need hardly point out that a chemical nucleus of this kind is not in the least what the biologist or cytologist means by the term cell-nucleus. The one is a subjective postulate necessary for the comprehension of the activities of any speck of living matter or any portion, however minute, of a living organism; the other is a concrete structure, known to us by actual observation, and as much an integral part of the true cell, considered as a definite type of organism, as a backbone or its morphological equivalent is essential to the definition of a true vertebrate.

different stains before a combination is found which will differentiate a given cytoplasmic enclosure from a true chromatin-grain by its colour-reactions. The so-called volutin-grains, for example, which are found commonly in the cytoplasm of many Protists, are identified by the fact that they have a stronger affinity for 'chromatin-stains' than chromatin itself.

When, moreover, chromatin is compared with regard to its staining-reactions, both in different organisms, and in the same organism at different times, it is found to react very differently to one and the same stain. A striking example of this capriciousness is seen when a preserved film is made of the blood of some vertebrate which has nucleated blood-corpuscles, such as a bird or fish, and which contains also parasitic trypanosomes. It is easy to stain the nuclei of the blood-corpuscles with various stains, as for example carmine-stains such as picro-carmine or alum-carmine, which will not colour the nuclei of the trypanosomes in the slightest. Moreover, every cytologist knows that the 'chromaticity' of the chromatin varies enormously in different phases of the nuclear cycle of generation; it is often difficult to stain the chromatin in the 'resting' nucleus, but the first sign of impending nuclear division is a marked increase in the staining powers of the chromatin. There is no dye known which can be relied upon to stain chromatin always, or wherever it occurs. Methyl green has been claimed to be the most reliable and certain of nuclear stains, but R. Hertwig, in his classical researches upon *Actinosphærium*, showed that it sometimes fails to stain chromatin. It is perfectly conceivable that there might be varieties of chromatin which could not be stained by any dye whatsoever.

I have felt bound to insist strongly upon the inadequacy of staining-methods for the detection and identification of chromatin, well known though these facts are to every cytologist, because here also I note a tendency amongst biological chemists to regard staining-properties as the sole criterion of chromatin. In reality such properties are of entirely secondary importance. To use the terminology of formal logic, staining-properties are an 'accident,' though it may be an 'inseparable accident,' of chromatin, not a 'difference' which can be used to frame a logical definition, *per genus et differentias*, of this substance. If chromatin were nothing more than 'stainable substance,' as Professor Armstrong terms it,[8] some of the most important results of cytological investigation would be deprived of all real significance and reduced to the merest futilities.

What then is the true criterion of the chromatin-substance of living organisms? From the chemical point of view the essential substance of the cell-nucleus would appear to be characterised by a complexity of molecular structure far exceeding that of any other proteins, as well as by certain definite peculiarities. Especially characteristic of chromatin is its richness in phosphorus-compounds, and it stands apart also from other cell-elements in its solvent reactions, for example, resistance to peptic digestion. E. B. Wilson, in his well-known treatise, has emphasised the 'cardinal fact . . . that there is a definite and constant contrast between nucleus and cytoplasm.' The outstanding feature of the nucleus is the constant presence in abundance of nuclein and nucleoproteins. Nuclein, which is probably identical with chromatin, is a complex albuminoid substance rich in phosphorus. It is the phosphorus-content of chromatin that is its most characteristic chemical peculiarity as contrasted with the cytoplasm. How far these features are common, however, to all samples of chromatin in all types of living organisms universally, cannot, I think, be stated definitely at present; at any rate, it is not feasible for a cytologist of these days to identify a granule in a living organism or cell as chromatin solely by its chemical reactions, although it is quite possible that at some future time purely chemical tests will be decisive upon this point—a consummation devoutly to be wished.

The only criterion of chromatin that is convincing to the present-day biologist is the test of its behaviour, that is to say, its relations to the life, activity, and development of the organism. I may best express my meaning by objective examples. If I make a preparation of *Arcella vulgaris* by suitable methods, I see the two conspicuous nuclei and also a ring of granules lying

[8] *Science Progress*, vol. vii. p. 327.

in the cytoplasm, stained in the same manner as the chromatin of the nuclei. Are these extranuclear granules to be regarded also as chromatin? Yes, most decidedly, because many laborious and detailed investigations have shown that from this ring of granules in *Arcella* nuclei can arise, usually termed 'secondary' nuclei for no other reason than that they arise *de novo* from the extranuclear chromatin and quite independently of the 'primary' nuclei. The secondary nuclei are, however, true nuclei in every respect, as shown by their structure, behaviour, and relations to the life-history of the organism; they may fuse as nuclei of gametes (pronuclei) in the sexual act and they become, with or without such fusion, the primary nuclei of future generations of *Arcella*; they then divide by karyokinesis when the organism reproduces itself in the ordinary way by fission, and are replaced in their turn by new secondary nuclei at certain crises in the life-history. In view of these facts it can be asserted without hesitation that the ring of staining granules in *Arcella* is composed of, or at least contains, true chromatin-grains, extranuclear chromatin for which R. Hertwig's term chromidia is now used universally. It is interesting to note that until the life-history of *Arcella* was studied in recent times the conspicuous ring of chromidia was generally overlooked and is not shown in some of the older pictures of the organism.

If, on the other hand, I make a preparation of some unidentified amœba occurring casually in pond-water or in an infusion, and find in its cytoplasm certain grains staining in same manner as the chromatin of the nucleus, it is quite impossible, without a knowledge of the life-history of the organism, to assert definitely that the grains in question are or are not true chromidia. They might equally well turn out to be volutin or any other substance that has an affinity for the particular chromatin-stains used in making the preparation.

The fact that at the present time the only decisive criterion of what is or is not chromatin is supplied only by its behaviour in the life-history and its relation to the organism, makes it much easier to identify the chromatin in some cases than in others. In those Protista or cells which contain, during the whole or a part of the life-history, one or more true nuclei, recognisable as such unmistakably by their structure and their characteristic relations to the reproductive and sexual phenomena of the organism, the chromatin can be identified with certainty. If chromidia occur in the cell-body in addition to true nuclei, or even if the nuclei are temporarily absent during certain crises of the life-history and the chromatin occurs then only in the form of chromidia, there is still no difficulty in identifying the scattered chromatin-grains by the fact that they contribute, soon or later, to the formation of nuclei.

On the other hand, in the simplest Protist organisms which do not contain definite, compact nuclei recognisable by their structure and behaviour, the identification of the chromatin may become correspondingly difficult. In the absence of definite chemical criteria the term chromatin acquires then a greater or less degree of vagueness and uncertainty of application, and it is not easy to avoid a tendency to a *petitio principii* in attempting to define or identify it. To a large extent we are thrown back upon the staining-reactions, which I have already shown to be very unreliable, backed up by analogies with those forms which possess definite nuclei. Since in the cells of all animals and plants, and in all Protista which possess a true nucleus, the chromatin is the one constituent which is invariably present, as I shall point out in more detail subsequently, there is at least a strong presumption, though not of course amounting to absolute proof, that it is present, or at least is represented by some similar and genetically homologous constituents, in the forms of simpler structure also. If then in Protista of primitive type we find certain grains which exhibit the characteristic staining-reactions of chromatin to be constantly present in the organism, grains which grow and divide as a preliminary to the organism multiplying by fission and which are partitioned amongst the daughter-organisms during the process of fission, so that each daughter-individual reproduces the structure of the parent-form from which it arose; then there is very strong *prima facie* evidence, to say the least, for regarding such grains as homologous with the chromatin-grains of ordinary cells.

Having now defined or explained, as well as I am able, the terms of which I am about to make use, I return to my main theme, the cell and its evolution. To summarise the points already discussed, a typical cell is a mass of protoplasm differentiated into two principal parts or regions, the cytoplasm and the nucleus, or, it may be, two or more nuclei. The cytoplasm may or may not contain chromatin-grains in addition to other enclosures, and may possess cell-organs of various kinds. The nucleus, highly variable in minute structure, possesses one invariable constituent, the chromatin-material in the form of grains and masses of various sizes.

The cell, therefore, in its complete and typical form, is an organism of very considerable complexity of structure and multiplicity of parts. The truth of this proposition is sufficiently obvious even from simple inspection of the structural details revealed by the microscope in cells in the so-called 'resting condition,' but still more so from a study of their activities and functions. The vital processes exhibited by the cell indicate a complexity of organisation and a minuteness in the details of its mechanism which transcend our comprehension and baffle the human imagination, to the same extent as do the immensities of the stellar universe. If such language seems hyperbolic, it is but necessary to reflect on some of the established discoveries of cytology, such as the extraordinary degree of complication attained in the process of division of the nucleus by karyokinesis, or the bewildering series of events that take place in the nuclei of germ-cells in the processes of maturation and fertilisation. Such examples of cell-activity give us, as it were, a glimpse into the workshop of life and teach us that the subtlety and intricacy of the cell-microcosm can scarcely be exaggerated.

On the assumption that an organism so complex and potent was not created suddenly, perfect and complete as it stands, but arose, like all other organisms, by progressive evolution and elaboration of some simpler form and type of structure, it is legitimate to inquire which of the various parts of the cell are the older and more primitive and which are more recent acquisitions in the course of evolution. But it must be clearly pointed out, to start with, that the problem posed in such an inquiry is perfectly distinct from, and independent of, another point which has often been discussed at length, namely, the question whether any parts of the cell, and if so which parts, are to be regarded as 'living' or 'active' in distinction to other parts which are to be regarded as 'not-living' or 'passive.' This discussion, in my opinion, is a perfectly futile one, of which I intend to steer clear.

We may agree that in any given cell or living organism, simple or complex in structure, all the parts are equally 'living' and equally indispensable for the maintenance of life, or at least for the continuance of the vital functions in the normal, specific manner, without losing the right to inquire which of those parts are the phylogenetically older. A simple analogy will serve to point my meaning. A man could not continue to live for long if deprived either of his brain, his digestive tract, his lungs, his heart, or his kidneys, and each of these organs is both 'living' in itself and at the same time an integral part of the entire organisation of the human body; yet no one would think of forbidding comparative anatomists to discuss, from the data at their command, which of these organs appeared earlier, and which later, in the evolution of the phylum Vertebrata. Moreover, speculative though such discussions must necessarily be, there is no one possessing even a first-year student's knowledge of the facts who would controvert the statement that the digestive tract of man is phylogenetically older than the lung. Speculative conclusions are not always those that carry the least conviction.

The evolution of the cell may be discussed as a morphological problem of the same order as that of the phylogeny of any other class or phylum of living beings, and by the same methods of inquiry. In the first place there is the comparative method, whereby different types of cell-structure can be compared with one another and with organisms in which the cell-structure is imperfectly developed, in order to determine what parts are invariable and essential and what are sporadic in occurrence and of secondary importance, and if possible to arrange the various structural types in one or more evolutionary series. Secondly there is the developmental or ontogenetic method, the study of the mode and sequence of the formation of the parts of the cell as they come into

existence during the life-history of the organism. Both these methods, which are founded mainly on observation, require to be checked and controlled by the experimental methods of investigating both the functions and behaviour of the organism and of its parts.

So long as cytologists limit their studies to the cells building up the tissues of the higher animals and plants, the comparative method has a correspondingly limited scope, and that of the ontogenetic method is even more restricted. Both methods receive at once, however, an enormously extended range when the Protista are taken into consideration. Then, moreover, we see the dawning possibility of another method of investigation, that, namely, of the chemical evolution of the organisms. Already some of the simpler Protista, the Bacteria, are characterised and classified largely by their chemical activities; but in more complex organisms, in those which have attained complete cell-structure, such as Protozoa, the data of chemistry do not as yet supply the evolutionist with a helpful method of investigation.

The problem of cell-evolution may be attacked by the help of the methods outlined in the foregoing remarks, beginning with the consideration of the primary structural differentiation of the typical cell, the distinction of nucleus, or rather chromatin, and cytoplasm. Since all cells known to us exhibit this differentiation, we have three possibilities as regards the manner in which it has come about, which may be summarised briefly as follows: either the cytoplasmic and chromatinic constituents of the cell have arisen as differentiations of some primitive substance, which was neither the one nor the other; or one of these two substances is a derivative of the other, in the course of evolution, either cytoplasm of chromatin, or chromatin of cytoplasm.

The idea of a primitive, undifferentiated protoplasmic substance was first put forward by Haeckel, who employed for it the term 'plasson' invented by Van Beneden[9] to denote 'la substance constitutive du corps des Monères et des cytodes . . . la substance formative par excellence.' The simplest elementary organisms were not cells, but cytodes, 'living independent beings which consist entirely of a particle of plasson; their quite homogeneous or uniform body consists of an albuminous substance which is not yet differentiated into karyoplasm and cytoplasm, but possesses the properties of both combined.'[10] It is emphasised[11] that a sharp distinction must be drawn between protoplasm and plasson, the latter being a homogeneous albuminous formative substance ('Bildungsstoff') corresponding to the 'Urschleim' of the older Nature-philosophy.

Haeckel, as was usual with him, did not content himself with putting forward his ideas as abstract speculations, but sought to provide them with a concrete and objective foundation by professing to have discovered, and describing in detail, living and existing organisms which were stated to remain permanently in the condition of cytodes. In consequence, a purely speculative notion was permitted to masquerade for many years under the false appearance of an objective phenomenon of Nature, until the error was discovered gradually and the phantom banished from the accepted and established data of biology. Organisms supposed to be of the nature of cytodes constituted Haeckel's systematic division Monera, of which there were supposed to be two subdivisions, the Phytomonera and the Zoomonera. The Phytomonera were stated to have the plasson coloured green and to live in a plant-like manner; the Zoomonera were colourless amœboid masses of plasson which nourished themselves in the animal manner. The Bacteria were also included by Haeckel in his Monera, apparently, or at all events ranked as cytodes.[12] Most importance, however, was attributed by Haeckel to the large amœboid forms of Monera, described as without nuclei of contractile vacuoles, but as representing simply structureless contractile masses of albumin ('Eiweiss'), perfectly homogeneous;[13] examples of these were announced to exist under the names 'Protamœba' and 'Protogenes,' denoting forms of life which Haeckel claimed

[9] *Bull. de l'Acad. Roy. de Belgique*, second series, vol. xxxi. (1871), p. 346.
[10] *Anthropogenie*, sixth edition, Leipzig, 1910, p. 119.
[11] *Ibid.* p. 532.
[12] *Ibid.* p. 119.
[13] See his *Prinzipien der generellen Morphologie*, Berlin, 1906, p. 61.

to have discovered, but which have never been found again by any other naturalist. These organisms, as described by Haeckel, were by no means such as the modern microscopist would call minute; on the contrary, they were relatively large, and some of the forms added to the Monera by Haeckel's contemporaries might even be termed gigantic, as, for example, the supposed organism *Bathybius*, discovered in the bottles of the *Challenger* Expedition, which was believed to cover large areas of the floor of the ocean with a layer of primordial protoplasm, but which proved finally to be a precipitation by alcohol of the gypsum in sea-water.

The theory of plasson and of the cytodes of Haeckel may be considered first from the purely speculative standpoint of the origin of the living substance, a problem with which I wish to become entangled here as little as possible, since it is my object to confine myself so far as possible to deductions and conclusions that may be drawn from known facts and concrete data of observation and experiment. If, however, we postulate a chemical evolution of protoplasm, and believe that every degree of complexity exists, or at least has existed, between the simplest inorganic compounds and the immensely complicated protein-molecules of which the living substance is composed, then no doubt chemical compounds may have existed which in some sense were intermediate in their properties between the two constituents, cytoplasm and chromatin, found in all known samples of the living substance of organisms. In this sense and on such a hypothesis, a substance of the nature of plasson may perhaps be recognised or postulated at some future time by the biochemist, but this is a subject which I am quite incompetent to discuss. To the modern biologist, who can deal only with living things as he knows them, Haeckel's plasson must rank as a pure figment of the imagination, altogether outside the range of practical and objective biology at the present time. All visible living things known and studied up to the present consist of protoplasm, that is to say, of an extremely heterogeneous substance of complex structure, and no living organism has been discovered as yet which consists of homogeneous structureless albuminous substance. Van Beneden, who is responsible for the word plasson, though not for the cytode-theory, was under the impression that he had observed a non-nucleated homogeneous cytode-stage in the development of the gregarine of the lobster, *Gregarina* (*Porospora*) *gigantea*. Without entering into a detailed criticism of Van Beneden's observations upon this form, it is sufficient to state that the development of gregarines is now well known in all its details, and that in all phases of their life-cycle these organisms show the complete cell-structure, and are composed of nucleus and cytoplasm. Moreover, all those organisms referred by Haeckel to the group Monera which have been recognised and examined by later investigators have been found to consist of ordinary cytoplasm containing nuclei or nuclear substance (chromatin). In the present state of biological knowledge therefore, the Monera as defined by Haeckel must be rejected and struck out of the systematic roll as a non-existent and fictitious class of organisms.

Since no concrete foundation can be found for the view that cytoplasm and chromatin have a common origin in the evolution of living things, we are brought back to the view that one of them must have preceded the other in phylogeny. The theories of evolution put forward by Haeckel and his contemporaries, if we abolish from them the notion of plasson and substitute for it that of ordinary protoplasm, would seem to favour rather the view that the earliest forms of life were composed of a substance of the nature rather of cytoplasm, and that the nuclear substance or chromatin appeared later in evolution as a product or derivative of the cytoplasm. I have myself advocated a view diametrically opposite to this, and have urged that the chromatin-substance is to be regarded as the primitive constituent of the earliest forms of living organisms, the cytoplasmic substance being a later structural complication. On this theory the earliest form of living organism was something very minute, probably such as would be termed at the present day 'ultra-microscopic.' After I had urged this view in the discussion on the origin of life at the Dundee Meeting of the British Association in 1912 a poem appeared in *Punch*,[14] dividing biologists into 'cytoplasmists' and 'chromatinists.'

[14] Vol. cxliii. p. 245.

must confess myself still a whole-hearted chromatinist. But before I consider this point I may refer briefly to some other speculations that have been put forward with regard to the nature of the earliest form of life. It is manifestly quite impossible that I should undertake here to review exhaustively all the theories and speculations with regard to the origin of life and the first stages in its evolution that have been put forward at different times. I propose to limit myself to the criticism of certain theories of modern times which, recognising the fundamental antithesis between chromatin and cytoplasm, regard these two cell-constituents as representing types of organisms primitively distinct, and suggest the hypothesis that true cells have arisen in the beginning as a process of symbiosis between them. Boveri, whose merits as a cytologist need no proclamation by me, was the first I believe to put forward such a notion; he enunciated the view that the chromosomes were primitively independent elementary organisms which live symbiotically with protoplasm, and that the organism known as the cell arose from a symbiosis between two kinds of simple organisms, 'Monera.'[15]

A similar idea lies at the base of the remarkable and ingenious speculations of Mereschkowsky,[16] who assumes a double origin for living beings from two sorts of protoplasm, supposed not only to differ fundamentally in kind but also to have had origins historically distinct. The first type of protoplasm he terms mycoplasm,[17] which is supposed to have come into existence during what he calls the third epoch[18] of the earth's history, at a time when the crust of the earth had cooled sufficiently for water to be condensed upon it, but when the temperature of the water was near boiling-point; consequently the waters of the globe were free from oxygen, while saturated with all kinds of mineral substances. The second type of protoplasm was amœboplasm, the first origin of which is believed to have taken place during a fourth terrestrial epoch when the waters covering the globe were cooled down below 50° C., and contained dissolved oxygen but fewer mineral substances. Corresponding with the differences of the epoch and the conditions under which they arose, Mereschkowsky's two types of protoplasm are distinguished by sharp differences in their nature and constitution.

Mycoplasm, of which typical examples are seen in bacteria, in the chromatin-grains of the nucleus and the chromatophores of plant-cells, is distinguished from amœboplasm, which is simply cytoplasm, by the following points. (1) Mycoplasm can live without oxygen, and did so in the beginning at its first appearance when the temperature of the hydrosphere was too high for it to have contained dissolved oxygen; only at a later period, when the temperature became low enough for the water to contain oxygen in solution, did some of the forms begin to adapt themselves to these conditions, and became secondarily facultative or obligate aerobes. Amœboplasm, on the other hand, cannot exist without a supply of oxygen. (2) Mycoplasm can support temperatures of 90° C. or even higher; amœboplasm cannot support a temperature higher than 45° C. or 50° C. (3) Mycoplasm is capable of building up albumins and complex organic substances from inorganic materials; amœboplasm is incapable of doing so, but requires organic food. (4) Mycoplasm has restricted powers of locomotion and is incapable of amœboid movement, or of forming the contractile vacuoles seen commonly in amœboplasm. (5) Mycoplasm, in contrast to amœboplasm, is rich in phosphorus and nuclein. (6) Mycoplasm is extraordinarily resistant to poisons and utilises as food many substances that are extremely deadly to amœboplasm, such as prussic acid, strychnine, and morphia.

[15] *Vide* Vejdovský, *l.c.* I have not had access to the work of Boveri, in which he is stated to have put forward these ideas.

[16] Mereschkowsky, C., 'Theorie der zwei Plasmaarten als Grundlage der Symbiogenesis, einer neuen Lehre von der Entstehung der Organismen.' *Biol. Centralblatt*, xxx. 1910, pp. 278-303, 321-347, 353-367.

[17] The term mycoplasm used by Mereschkowsky must not be confounded with the similar word used by Eriksson and other botanists in reference to the manner in which Rust-Fungi permeate their hosts.

[18] In the first epoch the earth was an incandescent mass of vapour; in the second it had a firm crust, but the temperature was far too high to permit of the condensation of water-vapour upon its surface.

(7) Amongst minor differences, mycoplasm is characterised by the presence of iron in the combined state and possesses a far more complicated structure than amœboplasm, a peculiarity which enables mycoplasmic cell-elements (chromosomes) to function as the bearers of hereditary qualities.

The course of the evolution of living beings, according to Mereschkowsky, was as follows. The earliest forms of life were 'Biococci,' minute ultra-microscopic particles of mycoplasm, without organisation, capable of existing at temperatures near boiling-point and in the absence of oxygen, possessing the power of building up proteins and carbohydrates from inorganic materials, and very resistant to strong mineral salts and acids and to various poisons. From the Biococci arose in the first place the Bacteria, which for a time were the only living inhabitants of the earth. Later, when the temperature of the terrestrial waters had been lowered below 50° C., and contained abundant organic food in the shape of Bacteria, amœboplasm made its appearance in small masses as non-nucleated Monera which crept in an amœboid manner on the floor of the ocean and devoured Bacteria.

The next step in evolution is supposed to have been that, in some cases, micrococci ingested by the Monera resisted digestion by them and were enabled to maintain a symbiotic existence in the amœboplasm. At first the symbiotic micrococci were scattered in the Moneran body, but later they became concentrated at one spot, surrounded by a membrane, and gave rise to the cell-nucleus. In this way, by a 'symbiogenesis' or process of symbiosis between two distinct types of organisms, Mereschkowsky believes the nucleated cell to have arisen, an immense step forward in evolution, since the locomotor powers of the simple and delicate Monera were now supplemented by the great capability possessed by the Bacteria of producing ferments of the most varied kinds.

Meanwhile it is supposed that the free Bacteria continued their natural evolution and gave rise to the Cyanophyceæ, and to the whole group of Fungi. The plant-cell came into existence by a further process of symbiogenesis, in that some of the Cyanophyceæ, red, brown, or green in colour, became symbiotic in nucleated cells, for the most part flagellates, in which they established themselves as the chromatophores or chlorophyll-corpuscles. In this way Mereschkowsky believes the vegetable cell to have come into existence, and the evolution of the Vegetable Kingdom to have been started, as a double process of symbiosis. Those amœboid or flagellated organisms, on the other hand, which formed no symbiosis with Cyanophyceæ, continued to live as animals and started the evolution of the Animal Kingdom.

As a logical deduction from this theory of the evolution of living beings, Mereschkowsky classifies organisms generally into three groups or Kingdoms: first the Mycoidea, comprising Bacteria, Cyanophyceæ, and Fungi, and in which no symbiosis has taken place; secondly, the Animal Kingdom, in which true cells have arisen by a simple symbiosis of mycoplasm (chromatin) and amœboplasm (cytoplasm); thirdly, the Vegetable Kingdom, in which true cells have entered upon an additional symbiosis with Cyanophyceæ, chromatophores or chlorophyll-corpuscles.

Interesting and suggestive as are the speculations of Mereschkowsky, they are nevertheless open to criticism from many points of view. I will not enter here into criticisms which I regard as beyond my competence. It is for botanists to pronounce upon the notion that Bacteria, Cyanophyceæ, and Fungi can be classified together as a group distinct from all other living beings; to decide whether the protoplasm of the Cyanophyceæ and Fungi can be regarded as consisting of mycoplasm alone, and not of a combination of nuclei and cytoplasm, such as is found in true cells and represents, according to Mereschkowsky, a symbiosis of mycoplasm and amœboplasm. I think I am right in saying that botanists are agreed in regarding Fungi as derived from green algæ, and as possessing nuclei similar to those of the higher plants. As a zoologist the point that strikes me most is the absence of any evidence that true Monera, organisms consisting of cytoplasm alone, exist or could ever have existed. Mereschkowsky supposes that when the Monera came into being they maintained their existence by feeding upon Bacteria. In order to digest Bacteria, however, the Monera must have been capable of producing ferments, and therefore did not acquire this power only as the result of symbiosis with Bacteria, unless it be assumed

that the symbiosis came about at the instant that amœboplasm came into existence. There is, however, no evidence that cytoplasm by itself can generate ferments. All physiological experiments upon the digestion of Protozoa indicates that the cytoplasmic body, deprived of the nucleus, cannot initiate the digestive process. Consequently the existence of purely cytoplasmic organisms would seem to be an impossibility.

For my part, I am unable to accept any theory of the evolution of the earliest forms of living beings which assumes the existence of forms of life composed entirely of cytoplasm without chromatin. All the results of modern investigations into the structure, physiology, and behaviour of cells on the one hand, and of the various types of organisms grouped under the Protista, on the other hand—the combined results, that is to say, of cytology and protistology—appear to me to indicate that the chromatin-elements represent the primary and original living units or individuals, and that the cytoplasm represents a secondary product. I will summarise briefly the grounds that have led me to this conviction, and will attempt to justify the faith that I hold; but first I wish to discuss briefly certain preliminary considerations which seem to me of great importance in this connection.

It is common amongst biologists to speak of 'living substance,' this phrase being preceded by either the definite or the indefinite article—by either 'the' or 'a.' If we pause to consider the meaning of the phrase, it is to be presumed that those who make use of it employ the term 'substance' in the usual sense to denote a form of matter to which some specific chemical significance can be attached, which could conceivably be defined more or less strictly by a chemist, perhaps even reduced to a chemical formula of some type. But the addition of the adjective 'living' negatives any such interpretation of the term 'substance,' since it is the fundamental and essential property of any living being that the material of which it is composed is in a state of continual molecular change and that its component substance or substances are inconstant in molecular constitution from moment to moment. When the body of a living organism has passed into a state of fixity of substance, it has ceased, temporarily or permanently, to behave as a living body; its fires are banked or extinguished. The phrase 'living substance' savours, therefore, of a *contradictio in adjecto*; if it is 'living' it cannot be a 'substance,' and if it is a 'substance' it cannot be 'living.'

As a matter of fact, the biologist, when dealing with purely biological problems, knows nothing of a living substance or substances; he is confronted solely by living individuals, which constitute his primary conceptions, and the terms 'life' and 'living substance' are pure abstractions. Every living being presents itself to us as a sharply-limited individual, distinct from other individuals and constituting what may be termed briefly a microcosmic unit, inasmuch as it is a unity which is far from being uniform in substance or homogeneous in composition, but which, on the contrary, is characterised by being made up of an almost infinite multiplicity of heterogeneous and mutually interacting parts. We recognise further that these living individuals possess invariably specific characteristics; two given living individuals may be so much alike that we regard them as of the same kind or 'species,' or they may differ so sharply that we are forced to distinguish between them specifically. Living beings are as much characterised by this peculiarity of specific individuality as by any other property or faculty which can be stated to be an attribute of life in general, and this is true equally of the simplest or the most complex organisms; at least we know of no form of life, however simple or minute, in which the combined features of individuality and specificity are not exhibited to the fullest extent. A living organism may be so minute as to elude direct detection entirely by our senses, even when aided by all the resources furnished by modern science; such an organism will, nevertheless, exhibit specific properties or activities of an unmistakable kind, betraying its presence thereby with the utmost certainty. The organisms causing certain diseases, for example, are ultra-microscopic, that is to say, they have not been made visible as yet, and an exact description or definition cannot be given of them at the present time; yet how strongly marked and easily distinguishable are the specific effects produced by the organisms causing respectively measles and small-pox, for instance, each, moreover, remaining strictly true and constant to its

specific type of activity; the organism, whatever its nature may be, which causes measles cannot give rise to small-pox, nor *vice versa*, but each breeds as true to type as do lions and leopards.

The essential and distinctive characteristic of a living body of any kind whatsoever is that it exhibits while it lives permanence and continuity of individuality or personality, as manifested in specific behaviour, combined with incessant change and lability of substance; and further, that in reproducing its kind, it transmits its specific characteristics, with, however, that tendency to variability which permits of progressive adaptation and gradual evolutionary change. It is the distinctively vital property of specific individuality combined with 'stuff-change' (if I may be allowed to paraphrase a Teutonic idiom) which marks the dividing line between Biochemistry and Biology. The former science deals with substances which can be separated from living bodies, and for the chemist specific properties are associated with fixity of substance; but the material with which the biologist is occupied consists of innumerable living unit-individuals exhibiting specific characteristics without fixity of substance. There is no reason to suppose that the properties of a given chemical substance vary in the slightest degree in space or time; but variability and adaptability are characteristic features of all living beings. The biochemist renders inestimable services in elucidating the physico-chemical mechanisms of living organisms; but the problem of individuality and specific behaviour, as manifested by living things, is beyond the scope of his science, at least at present. Such problems are essentially of distinctively vital nature and their treatment cannot be brought satisfactorily into relation at the present time with the physico chemical interactions of the substances composing the living body. It may be that this is but a temporary limitation of human knowledge prevailing in a certain historical epoch, and that in the future the chemist will be able to correlate the individuality of living beings with their chemico-physical properties, and so explain to us how living beings first came into existence; how, that is to say, a combination of chemical substances, each owing its characteristic properties to a definite molecular composition, can produce a living individual in which specific peculiarities are associated with matter in a state of flux. But it is altogether outside the scope and aim of this address to discuss whether the boundary between biochemistry and biology can be bridged over, and if so, in what way. I merely wish to emphasise strongly that if a biologist wishes to deal with a purely biological problem, such as evolution or heredity, for example, in a concrete and objective manner, he must do so in terms of living specific individual units. It is for that reason that I shall speak, not of the chromatin-substance but of chromatinic elements, particles or units, and I hope that I shall make clear the importance of this distinction.

To return now to our chromatin; I regard the chromatinic elements as being those constituents which are of primary importance in the life and evolution of living organisms mainly for the following reasons: the experimental evidence of the preponderating physiological *rôle* played by the nucleus in the life of the cell; the extraordinary individualisation of the chromatin-particles seen universally in living organisms, and manifested to a degree which raises the chromatinic units to the rank of living individuals exhibiting specific behaviour, rather than that of mere substances responsible for certain chemico-physical reactions in the life of the organism; and last, but by no means least, the permanence and, if I may use the term, the immortality of the chromatinic particles in the life-cycle of organisms generally. I will now deal with these points in order; my arguments relate, in the first instance, to those organisms in which the presence of true cell-nuclei renders the identification of the chromatin-elements certain, as pointed out above, but if the arguments are valid in such cases they are almost certainly applicable also to those simpler types of organisms in which the identification of chromatin rests on a less secure foundation.

The results obtained by physiological experiments with regard to the functions of the nuclear and cytoplasmic constituents of the cell are now well known and are cited in all the text-books. It is not necessary, therefore, that I should discuss them in detail. I content myself with quoting a competent and impartial summary of the results obtained:

'A fragment of a cell deprived of its nucleus may live for a considerable time and manifest the power of co-ordinated movements without perceptible impairment. Such a mass of protoplasm is, however, devoid of the powers of assimilation, growth, and repair, and sooner or later dies. In other words, those functions that involve destructive metabolism may continue for a time in the absence of the nucleus; those that involve constructive metabolism cease with its removal. There is, therefore, strong reason to believe that the nucleus plays an essential part in the constructive metabolism of the cell, and through this is especially concerned with the formative processes involved in growth and development. For these and many other reasons . . . the nucleus is generally regarded as a controlling centre of cell-activity, and hence a primary factor in growth, development, and the transmission of specific qualities from cell to cell, and so from one generation to another.'[19]

I may add here that the results of the study of life-cycles of Protozoa are entirely in harmony with this conception of the relative importance of nuclear —that is chromatinic—and cytoplasmic cell-constituents, since it is not infrequent that in certain phases of the life-cycle, especially in the microgamete-stages, the cytoplasm is reduced, apparently, to the vanishing point, and the body consists solely of chromatin, so far as can be made out. In not one single instance, however, has it been found as yet that any normal stage in the developmental cycle of organisms consists solely of cytoplasm without any particles of chromatin.

While on the subject of physiological experiment, there is one point to which I may refer. Experiments so far have been carried on with Protozoa possessing definite nuclei. It is very desirable that similar experiments should be conducted with forms possessing chromidia in addition to nuclei, in order to test the physiological capabilities of chromatin-particles not concentrated or organised *Arcella* would appear to be a very suitable form for such investigations. This is a point to which my attention was drawn by my late friend Mr. C. H. Martin, who has lost his life in his country's service.

I have mentioned already in my introductory remarks that the only reliable test of chromatin in its behaviour, and the whole of modern cytological investigation bears witness to the fact that the chromatinic particles exhibit the characteristic property of living things generally, namely, individualisation combined with specific behaviour. In every cell-generation in the bodies of ordinary animals and plants the chromatin-elements make their appearance in the form of a group of chromosomes, not only constant in number for each species, but often exhibiting such definite characteristics of size and form, that particular, individual chromosomes can be recognised and identified in each group throughout the whole life-cycle. Each chromosome is to be regarded as an aggregate composed of a series of minute chromatinic granules or chromioles, a point which I shall discuss further presently. Most striking examples of the individualisation of chromosomes have been made known recently by Dobell and Jameson[20] in Protozoa. Thus in the Coccidian genus *Aggregata* six chromosomes appear at every cell-generation, each differing constantly in length if in the extended form, or in bulk if in the contracted form, so that each of the six chromosomes can be recognised and denoted by one of the letters *a* to *f* at each appearance, *a* being the longest and *f* the shortest.

Even more remarkable than the relation of the chromosome to cell-reproduction is their behaviour in relation to sexual phenomena. In the life-cycles of Metazoa the sexual act consists of the fusion of male and female pronuclei, each containing a definite and specific number of chromosomes, the same number usually, though not always, in each pronucleus. It has been established in many cases, and it is perhaps universally true, that in the act of fertilisation the male and female chromosomes remain perfectly distinct and separate in the synkaryon or nucleus formed by the union of the two pronuclei, and, moreover, that they continue to maintain and to propagate their distinct individuality in every subsequent cell-generation of the multicellular organism produced as a result of the sexual act. In this way, every cell of the body contains in its nucleus distinct chromatinic elements which are derived from

[19] E. B. Wilson, *The Cell*, second edition, 1911, pp. 30 and 31.
[20] *Proc. Roy. Soc.* (B), vol. 89. (*In the Press.*)

both male and female parents and which maintain unimpaired their distinct and specific individuality through the entire life-cycle. This distinctness is apparent at least in the germ-cell-cycle of the organism, but may be obscured by secondary changes in the nuclei of the specialised tissue-cells.

Only in the very last stage of the life-cycle do the group of male and female chromosomes modify their behaviour in a most striking manner. In the final generation of oogonia or spermatogonia, from which arise the oocytes and spermatocytes which in their turn produce the gamete-cells, it is observed that the male and female chromosomes make a last appearance in their full number, and then fuse in pairs, so as to reduce the number of chromosomes to half that previously present.

In *Aggregata* also Dobell and Jameson have shown that the union of the pronuclei in fertilisation brings together two sets each of six chromosomes, and that these then fuse with one another in pairs according to type, that is to say *a* with *a*, *b* with *b*, *c* with *c*, and so on. Analogous phenomena have been demonstrated also in the gregarine *Diplospora*. We have here a difference in detail, as compared with the Metazoa, in that the fusion takes place at the fertilisation and not as the first step in the maturation of the germ-cells; but in both cases alike the fusion of chromatin-elements individually distinct and exhibiting specific characteristics is to be regarded as the final consummation of the sexual act, though long deferred in the Metazoan life-cycle.

As Vejdovský has pointed out, there can be no more striking evidence of the specific individuality of the chromosomes than their fusion or copulation in relation to the sexual act. Is there any other constant element or constituent of living organisms exhibiting to anything like the same degree the essentially vital characteristics of individuality manifested in specific behaviour? If there is, it remains to be discovered.

I come now to the question of the permanence and immortality, in the biological sense of the word, of the chromatinic particles, which may be summarily stated as follows: the chromatinic particles are the only constituents of the cell which maintain persistently and uninterruptedly their existence throughout the whole life-cycle of living organisms universally.

I hope I shall not be misunderstood when I enunciate this apparently sweeping and breathless generalisation. I am perfectly aware that in the life-cycle of any given species of organism there may be many cell-constituents besides the chromatin-particles that are propagated continuously through the whole life-cycle; but cell-elements which appear as constant parts of the organisation of the cell throughout the life-cycle in one type of organism may be wanting altogether in other types. With the exception of the chromatin-particles there is no cell-constituent that can be claimed to persist throughout the life-cycles of organisms universally. To take some concrete examples: the cytoplasmic grains known as mitochondria or chrondriosomes have been asserted to be persistent elements throughout the germ-cycle of Metazoa, and the function of being the bearers of hereditary tendencies has been ascribed to them. But Vejdovský [21] flatly denies the alleged continuity in cases investigated by him, and though chrondriosomes have been described in some Protozoa, there is no evidence whatever that they are of universal occurrence in Protista. Centrosomes, intranuclear or extranuclear, have been stated to be constant cell-components in some organisms; whether that is true or not it seems quite certain that in many organisms the cells are entirely without centrosomic bodies of any kind, as for example in the whole group of Phanerogams. So it is with any other cell-constituent that can be named. It may be that this is only the result of our incomplete knowledge at the present time. I am prepared, however, to challenge anyone to name or to discover any cell-constituent, other than the chromatinic particles, which are present throughout the life-cycle, not merely of some particular organism, but of organisms universally.

In this feature of continuity the chromatin-constituents of the cell present a remarkable analogy with the germ-plasm of Metazoa. Just as the germ-cells of Metazoa go on in an uninterrupted, potentially everlasting series of cell-generations, throwing off, as it were, at each sexual crisis a soma which is doomed to but a limited lease of life, during which it furnishes a nutritive

[21] *L.c.* pp. 77-89.

environment for further generations of germ cells; so in the series of cell-generations themselves, whether in the germ-cell-cycles of Metazoa or in the life-cycles of Protista the chromatin-particles maintain an uninterrupted propagative series within a cell-body of which the various parts have a limited duration of existence, making their appearance, flourishing for a time, and disappearing again. This analogy between the chromatin of cells and the germ-plasm of multicellular organisms becomes still more marked when we find that in many Protozoa the chromatin may undergo a specialisation into generative and trophic chromatin, the former destined to persist from one life-cycle to another, the latter destined to control cell-activities merely during one cycle, without persisting into the next. The differentiation of generative and trophic chromatin is now well known to occur in many Protozoa, and in its most extreme form, as seen in the Infusoria, it is expressed in occurrence of two distinct nuclei in the cell-body.

To recapitulate my argument in the briefest form; the chromatinic constituents of the cell contrast with all the other constituents in at least three points: physiological predominance, especially in constructive metabolism; specific individualisation; and permanence in the sense of potential biological immortality. Any of these three points, taken by itself, is sufficient to confer a peculiar distinction, to say the least, on the chromatin-bodies; but taken in combination they appear to me to furnish overwhelming evidence for regarding the chromatin-elements as the primary and essential constituents of living organisms, and as representing that part of a living body of any kind which can be followed by the imagination, in the reverse direction of the propagative series, back to the very starting-point of the evolution of living beings.

In the attempt to form an idea as to what the earliest type of living being was like, in the first place, and as to how the earliest steps in its evolution and differentiation came about, in the second place, we have to exercise the constructive faculty of the imagination guided by such few data as we possess. It is not to be expected, therefore, that agreement can be hoped for in such speculations; it would indeed be very undesirable, in the interests of science, that there should be no conflict of opinion in theories which, by their very nature, are beyond any possibility of direct verification at the present time The views put forward by any man do but represent the visions conjured up by his imagination, based upon the slender foundation of his personal knowledge, more or less limited, or intuition, more or less fallacious, of an infinite world of natural phenomena. Consequently such views may be expected to diverge as widely as do temperaments. If, therefore, I venture upon such speculations, I do so with a sense of personal responsibility and as one wishing to stimulate discussion rather than to lay down dogma.

To me, therefore, the train of argument that I have set forth with regard to the nature of the chromatinic constituents of living organisms appear to lead to the conclusion that the earliest living beings were minute, possibly ultra-microscopic particles which were of the nature of chromatin How far the application of the term chromatin to the hypothetical primordial form of life is justified from the point of view of substance, that is to say in a biochemical sense, must be left uncertain. In using the term chromatin I must be understood to do so in a strictly biological sense, meaning thereby that these earliest living things were biological units or individuals which were the ancestors, in a continuous propagative series, of the chromatinic grains and particles known to us at the present day as universally-occurring constituents of living organisms. Such a conception postulates no fixity of chemical nature; on the contrary, it implies that as substance the primitive chromatin was highly inconstant, infinitely variable, and capable of specific differentiation in many divergent directions.

For these hypothetical primitive organisms we may use Mereschkowsky's term biococci. They must have been free-living organisms capable of building up their living bodies by synthesis of simple chemical compounds. We have as yet no evidence of the existence of biococci at the present time as free-living organisms; the nearest approach to any such type of living being seems to be furnished by the organisms known collectively as Chlamydozoa, which up to the present have been found to occur only as pathogenic parasites. In view,

however, of the minuteness and invisibility of these organisms, it is clear that they could attract attention only by the effects they produce in their environment. Consequently the human mind is most likely to become aware in the first instance of those forms which are the cause of disturbance in the human body. If free-living forms of biococci exist, as is very possible and even probable, it is evident that very delicate and accurate methods of investigation would be required to detect their presence.

I am well aware that the nature and even the existence of the so-called Chlamydozoa is uncertain at the present time, and I desire to exercise great caution in basing any arguments upon them. In the descriptions given of them, however, there are some points which, if correctly stated, seem to me of great importance. They are alleged to appear as minute dots, on the borderline of microscopic visibility or beyond it; they are capable of growth, so that a given species may be larger or smaller at different times; their bodies stain with the ordinary chromatin-stains; and they are stated to reproduce themselves by a process of binary fission in which the body becomes dumbbell-shaped, appearing as two dots connected by a slender thread, which is drawn out until it snaps across and then the broken halves of the thread are retracted into the daughter-bodies This mode of division, strongly reminiscent of that seen in centrioles, appears to me to permit of certain important conclusions with regard to the nature of these bodies; namely, that the minute dot of substance has no firm limiting membrane on the surface and that it is of a viscid or semi-fluid consistence.

If it be permissible to draw conclusions with regard to the nature of the hypothetical biococci from the somewhat dubious, but concrete data furnished by the Chlamydozoa, the following tentative statements may be postulated concerning them. They were (or are) minute organisms, each a speck or globule of a substance similar in its reactions to chromatin. Their substance could be described as homogeneous with greater approach to accuracy than in the case of any other living organism, but it is clear that no living body that is carrying on constructive and destructive metabolism could remain for a moment perfectly homogeneous or constant in chemical composition. Their bodies were not limited by a rigid envelope or capsule. Reproduction was effected by binary fission, the body dividing into two with a dumbbell-shaped figure. Their mode of life was vegetative, that is to say, they reacted upon their environmental medium by means of ferments secreted by their own body-substance. The earliest forms must have possessed the power of building up their protein-molecules from the simplest inorganic compounds; but different types of biococci, characterised each by specific reactions and idiosyncrasies, must have become differentiated very rapidly in the process of evolution and adaptation to divergent conditions of life.

Consideration of the existing types and forms of living organisms shows that from the primitive biococcal type the evolution of living things must have diverged in at least two principal directions. Two new types of organisms arose, one of which continued to specialise further in the vegetative mode of life, in all its innumerable variations, characteristic of the biococci, while the other type developed an entirely new habit of life, namely a predatory existence. I will consider these two types separately.

(1) In the vegetative type the first step was that the body became surrounded by a rigid envelope. Thus came into existence the bacterial type of organism, the simplest form of which would be a Micrococcus, a minute globule of chromatin surrounded by a firm envelope. From this familiar type an infinity of forms arise by processes of divergent evolution and adaptation. With increase in size of the body the number of chromatin-grains within the envelope increase in number, and are then seen to be imbedded in a ground-substance which is similar to cytoplasm, apparently, and may contain non-chromatinic enclosures. With still further increase of size the chromatin-grains also increase in number and may take on various types of arrangement in clumps, spherical masses, rodlets, filaments straight or twisted in various ways, or even irregular strands and networks,[22] and the cytoplasmic matrix, if it is

[22] See especially Dobell, 'Contributions to the Cytology of the Bacteria,' *Quart. Journ. Micr. Science*, lvi. (1911), pp. 461, 462. I cannot follow Dobell in applying the term 'nuclei' to these various arrangements of the chromatin-

correct to call it so, becomes correspondingly increased in quantity. I will not attempt, however, to follow up the evolution of the bacterial type further, nor to discuss what other types of living organisms may be affiliated with it, as I have no claims to an expert knowledge of these organisms. I prefer to leave to competent bacteriologists and botanists the problem of the relationships and phylogeny of the Cyanophyceæ, Spirochætes, &c., which have been regarded as having affinities with Bacteria.

(2) In the evolution from the biococcus of the predatory type of organism, the data at our disposal appear to me to indicate very clearly the nature of the changes that took place, as well as the final result of these changes, but leave us in the dark with regard to some of the actual details of the process. The chief event was the formation, round the biococci of an enveloping matrix of protoplasm for which the term periplasm (Lankester) is most suitable. The periplasm was an extension of the living substance which was distinct in its constitution and properties from the original chromatinic substance of the biococcus. The newly-formed matrix was probably from the first a semi-fluid substance of alveolar structure and possessed two important capabilities as the result of its physical structure; it could perform streaming movements of various kinds, more especially amœboid movement; and it was able to form vacuoles internally. The final result of these changes was a new type of organism which, compared with the original biococci, was of considerable size, and consisted of a droplet of alveolar, amœboid periplasm in which were imbedded a number of biococci. Whether this periplasm made its first appearance around single individual biococci, or whether it was from the first associated with the formation of zoogloea-like colonies of biococci, must be left an open question.

Thus arose in the beginning the brand of Cain, the prototype of the animal, that is to say, a class of organism, which was no longer able to build up its substance from inorganic materials in the former peaceful manner, but which nourished itself by capturing, devouring, and digesting other living organisms. The streaming movements of the periplasm enabled it to flow round and engulph other creatures; the vacuole-formation in the periplasm enabled it to digest and absorb the substance of its prey by the help of ferments secreted by the biococci By means of these ferments the ingested organisms were killed and utilised as food, their substance being first broken down into simpler chemical constituents and then built up again into the protein-substances composing the body of the captor.

A stage of evolution is now reached which I propose to call the pseudo moneral or cytodal stage, since the place of these organisms in the general evolution of life corresponds very nearly to Haeckel's conception of the Monera as a stage in the evolution of organisms, though not at all to his notions with regard to their composition and structure. The bodies of these organisms did not consist of a homogeneous albuminous 'plasson,' but of a periplasm corresponding to the cytoplasm of the cell, containing a number of biococci or chromatin-grains. Thus their composition corresponded more clearly to that of plasson as conceived by Van Beneden, when he wrote: 'Si un noyau vient à disparaître dans une cellule, si la cellule redevient un cytode, les éléments chimiques du noyau et du nucléole s'étant repandus dans le protoplasme, le plasson se trouve de nouveau constitué.' If we delete from this sentence the word 'chimiques' and also the words 'et du nucléole,' and substitute for the notion of the chemical solution of the chromatin-substance that of scattered chromatin-grains in the periplasm, we have the picture of the cytodal stage of evolution such as I have imagined it. It should be borne in mind that the ultimate granules of chromatin are probably in many cases ultra-microscopic; consequently they might appear to be dissolved in this cytoplasm when really existing as discrete particles.

In the life-cycles of Protozoa, especially of Rhizopods, it is not at all infrequent to find developmental phases which reproduce exactly the picture of the

grains in Bacteria. Vejdovský compares them with chromosomes; but there is no evidence that they play the part in the division and distribution of the chromatin-grains which is the special function of chromosomes, as will be discussed in more detail presently.

pseudo-moneral stage of evolution, phases in which the nucleus or nuclei have disappeared, having broken up into a number of chromatin-grains or chromidia scattered through the cytoplasm. We do not know as yet of any Protozoa, however, which remain permanently in the cytodal stage, that is to say, in which the chromatin-grains remain permanently in the scattered chromidial condition, without ever being concentrated and organised into true nuclei; but it is quite possible that some of the primitive organisms known as Proteomyxa will be found to exhibit this condition and to represent persistent Pseudomonera or cytodes.

The next stage in evolution was the organisation of the chromatin-grains (biococci) into a definite cell-nucleus. This is a process which can be observed actually taking place in many Protozoa in which 'secondary' nuclei arise from chromidia. It seems not unreasonable to suppose that a detailed study of the manner in which secondary nuclei are formed in Protozoa will furnish us with a picture, or rather series of pictures, of the method in which the cell-nucleus arose in phylogeny. To judge from the data supplied by actual observation, the evolution of the nucleus, though uniform in principle, was sufficiently diversified in the details of the process. As one extreme we have the formation of a dense clump of small, separate chromatin-grains, producing a granular nucleus of the type seen in Dinoflagellates, in Hæmogregarines, and in Diatoms Amongst the chromatin-grains there may be present also one or more grains or masses of plastin forming true nucleoli. At the opposite extreme a clump of chromatin-grains becomes firmly welded together into a single mass in which the individual grains can no longer be distinguished, forming a so-called karyosome, consisting of a basis of plastin cementing or imbedding the chromatin-grains into a mass of homogeneous appearance. Whatever the type of nucleus formed, the concentration of the chromidia into nuclei does not necessarily involve all the chromidia, many of which may remain free in the cytoplasm.

In the chromidial condition the chromatin-grains scattered in the cytoplasm are lodged at the nodes of the alveolar framework.[23] Consequently a supporting framework of cytoplasmic origin, the foundation of the linin-framework, was probably a primary constituent of the cell-nucleus from the first. In many nuclei of the karyosomatic type it is very difficult to make out anything of the nature of a framework, which, however, in other cases is seen clearly as delicate strands radiating from the karyosome to the wall of the vacuole in which the karyosome is suspended. Probably such a framework is present in all cases, and each supporting strand is to be interpreted as the optical section of the partition between two protoplasmic alveoli.

With the formation of the nucleus the cytode or pseudo-moneral stage has become a true cell of the simplest type, for which I propose the term *protocyte*. It is now the starting-point of an infinite series of further complications and elaborations in many directions. It is clearly impossible that I should do more than attempt to indicate in the most summary manner the various modifications of the cell-type of organism, since to deal with them conscientiously would require a treatise rather than an address, and, moreover, many such treatises exist already. The most conspicuous modifications of cell-structure are those affecting the periplasm, or, as we may now term it, the cytoplasm. In the first place, the cell as a whole takes various forms; primitively a little naked mass of protoplasm tending to assume a spherical form under the action of surface-tension when at rest, the cell-body may acquire the most diverse specific forms maintained either by the production of envelopes or various kinds of exoskeletal formations on the exterior of the protoplasmic body, or of supporting endoskeletal structures formed in the interior. The simple amœboid streaming movements become highly modified in various ways or replaced by special locomotor mechanisms or organs, flagella, cilia, &c., of various kinds. The internal alveolar cytoplasm develops fibrillæ and other structures of the most varied nature and function, contractile, skeletal, nervous, and so forth. The vacuole-

[23] Cf. Dobell, 'Observations on the Life-History of Cienkowski's *Arachnula*,' *Arch. Protistenkunde*, xxxi. (1913), p. 322. The author finds that in *Arachnula* each nucleus arises from a single chromatin-grain, which grows to form a vesicular nucleus. Since the fully-formed nucleus contains numerous grains of chromatin, the original chromidiosome must multiply in this process.

system may be amplified and differentiated in various ways and the cytoplasm acquires manifold powers of internal or external secretion. And finally the cytoplasm contains enclosures of the most varied kind, some of them metaplastic products of the anabolic or catabolic activity essential to the maintenance of life, others of the nature of special cell-organs performing definite functions, such as centrosomes, plastids, chromatophores, &c., of various kinds.

With all the diverse modifications of the cytoplasmic cell-body the nucleus remains comparatively uniform. It may indeed vary infinitely in details of structure, but in principle it remains a concentration or aggregation of numerous grains of chromatin supported on some sort of framework over which the grains are scattered or clumped in various ways, supplemented usually by plastin or nucleolar substance either as a cementing ground-substance or as discrete grains, and the whole marked off sharply from the surrounding cytoplasm, with or without a definite limiting membrane. There is, however, one point in which the nucleus exhibits a progressive evolution of the most important kind. I refer to the gradual elaboration and perfection of the reproductive mechanism, the process whereby, when the cell reproduces itself by fission, the chromatin-elements are distributed between the two daughter-cells.

The chromatin-constituents of the cell are regarded, on the view maintained here, as a number of minute granules, each representing a primitive independent living individual or biococcus. To each such granule must be attributed the fundamental properties of living organisms in general; in the first place metabolism, expressed in continual molecular change, in assimilation and in growth, with consequent reproduction; in the second place specific individuality. As the result of the first of these properties the chromatin-granules, often perhaps ultra-microscopic, may be larger or smaller at different times, and they multiply by dividing each into two daughter-granules. As a result of the second property, chromatin-granules in one and the same cell may exhibit qualitative differences and may diverge widely from one another in their reactions and effects on the vital activities of the cell. The chromatin-granules may be either in the form of scattered chromidia or lodged in a definite nucleus. When in the former condition, I have proposed the term chromidiosome[24] for the ultimate chromatinic individual unit; on the other hand, the term chromiole is commonly in use for the minute chromatin-grains of the nucleus. The terms chromidiosome and chromiole distinguish merely between the situation in the cell, extranuclear or intranuclear, of the individual chromatin-grain or biococcus.

In the phase of evolution that I have termed the pseudomoneral or cytodal phase, in which the organism was a droplet of periplasm containing scattered biococci or chromidiosomes, metabolism would result in an increase in the size of the cytode-body as a whole, accompanied by multiplication of the chromidiosomes. Individualisation of the cytodes would tend to the acquisition of a specific size, that is to say, to a limitation of the growth, with the result that when certain maximum dimensions were attained the whole cytode would divide into two or more smaller masses amongst which the chromidiosomes would be partitioned.

In the next stage of evolution, the protocyte with a definite nucleus, it is highly probable that at each division of the cell-body, whether into two or more parts, the primitive method of division of the nucleus was that which I have termed elsewhere 'chromidial fragmentation';[25] that is to say, the nucleus broke up and became resolved into a clump of chromidiosomes, which separated into daughter-clumps from which the daughter-nuclei were reconstituted. Instances of nuclear divisions by chromidial fragmentation are of common occurrence among the Protozoa and represent probably the most primitive and direct mode of nuclear division.

It is clear, however, that if the chromatin grains are to be credited with specific individuality and qualitative differences amongst themselves, this method of nuclear division presents grave imperfections and disadvantages, since even the quantitative partition of the chromatin is inexact, while the qualitative partition is entirely fortuitous. Chromidiosomes having certain

[24] *Introduction of the Study of the Protozoa*, Arnold, 1912, p. 65.
[25] *Op. cit.* p. 101.

specific properties might all become accumulated in one daughter-cell, and those having opposite properties in the other, so that the two daughter-cells would then differ entirely in their properties.

I can but refer briefly here in passing to the interesting theory put forward by Butschli, to the effect that sexual phenomena owe their first origin to differences between cellular organisms resulting from the imperfections of the primitive methods of cell-division. If we assume, for instance, as so many have done, that one of the earliest qualitative differences between different chromatin-granules was that while some influenced more especially the trophic activities of the cell, others were concerned specially with kinetic functions; then it might easily happen, after nuclear division by chromidial fragmentation, that all, or the majority of, the kinetic elements pass into one of the two daughter-cells, while its twin-sister obtains an undue preponderance of trophic chromatin. As a consequence, some cells would show strong kinetic but feeble trophic energies and others the opposite condition, and in either case the viability of the cells would be considerably impaired, perhaps inhibited. If it be further assumed that cells of opposite tendencies, kinetic and trophic, attract one another, it is easy to see that the union and fusion of two such cells, the one unduly kinetic (male) in character, the other with a corresponding trophic (female) bias, would restore equilibrium and produce a normal cell with kinetic and trophic functions equally balanced. On this view, sexual union, at its first appearance, was a natural remedy for the disadvantages arising from imperfect methods of nuclear division.

It is not surprising, therefore, to find that the process of nuclear division undergoes a progressive elaboration of mechanism which has the result of ensuring that the twin sister-granules of chromatin produced by division of a single granule shall be distributed between the two daughter-cells, so that for every chromatin-grain obtained by one daughter-cell an exact counterpart is obtained by the other; in other words, of ensuring an exact qualitative, as well as quantitative, partition of the chromatin-particles. In its perfect form this type of nuclear division is known as karyokinesis or mitosis, and all stages in its progressive development are to be found in the Protozoa.

In the evolution of nuclear division by karyokinesis two distinct processes are being developed and perfected in a parallel manner, but more or less independently; first, the method of the partition and distribution of the chromatin-grains between the two daughter-nuclei; secondly, the mechanism whereby the actual division of the nucleus and the separation of the two daughter-nuclei are effected in the cell-division. I have dealt elsewhere [26] with the evolution of the mechanism of karyokinesis as exemplified by the numerous and varied types of the process found amongst the Protozoa, and I need not discuss the matter further here, but the behaviour of the chromatin-grains may be dealt with briefly. The main feature in the process of the exact quantitative and qualitative distribution of the daughter-chromatin between the daughter-nuclei is the aggregation of the chromatin-grains or chromioles into definite, highly individualised structures known as chromosomes. In the most perfected forms of the process of chromosome-formation the chromioles become united into a linear series termed by Vejdovský a chromoneme, which is supported upon a non-chromatinic basis or axis. According to Vejdovský, the supporting substance consists of linin; R. Hertwig, however, in his well-known studies on *Actinosphærium* [27] considers that the supporting and cementing substance of the chromosome is plastin derived from the substance of the nucleoli. However that may be, the essential feature of the chromosome is the cementing together of the chromioles to form the chromoneme, a thread of chromatin which may be disposed in various ways on the supporting axis, sometimes being wound spirally round it (Vejdovský).

The actual division of the chromatin takes place by the longitudinal splitting of the chromoneme, in other words, by simultaneous division into two of each of the chromioles of which the thread is composed. In this way every chromiole which was contained in the original chromoneme is represented by a daughter-chromiole in each of the two daughter-chromonemes. It follows

[26] *Op. cit.* pp. 105-120.

[27] *Abhandl. bayer. Akad.* (II. Cl.) xix. 1898.

that the familiar process of the splitting of the chromosomes in karyokinesis is a mechanism which brings about in the most simple, sure and direct manner an exact quantitative and qualitative partition of the chromatin-grains between the two daughter-nuclei. In the sequel each daughter-nucleus is built up, according to Vejdovský, entirely and solely from one of the two daughter clumps of chromosomes, and each chromosome is resolved again into its constituent chromioles, giving rise in some cases to a definite portion of the nucleus, a karyomere, from which again, at the next nuclear division, the chromosome is reconstituted by the chromioles falling into line in an orderly manner.

The chromatin-cycle of a cell in which the process of division by karyokinesis takes place in its most perfectly developed form, may, therefore, be conceived as follows. The nucleus in its resting state contains a definite number of companies or brigades of chromatinic units (chromioles), each brigade spread over a certain extent of the nuclear framework forming a karyomere. As a preparation to division each separate brigade of chromioles falls into line as the chromoneme, forming with its supporting substance the chromosome; there are formed, therefore, just so many chromosomes as there were karyomeres in the nucleus In this disciplined and orderly array each chromiole undergoes its division into two daughter-chromioles, so that each file or chromoneme of chromioles splits into two files. At the reconstitution of the daughter-nuclei each daughter-chromosome gives rise to a karyomere again, the chromioles falling out of the ranks and disposing themselves in an apparently irregular manner on the newly-built framework of the daughter-nucleus to constitute their own particular karyomere. Thus karyokinesis differs only from the most primitive method of division by chromidial fragmentation in that what was originally a haphazard method of distribution has become a disciplined and orderly manœuvre, performed with the precision of the parade-ground, but in a space far less than that of a nutshell.

In the nuclear division of Protozoa, without going into excessive detail, it may be stated broadly that all stages are to be found of the gradual evolution of the tactical problem which constitutes karyokinesis. The chromosomes in the more primitive types of nuclear division are usually very numerous, small, irregular in number and variable in size; the splitting of the chromosomes is often irregular and not always definitely longitudinal; and distinct karyomeres have not so far been recognised in the nuclei of Protozoa. In many cases only a part, if any, of the chromatin falls in to form the chromosomes, and a greater or less amount of it remains in the karyosome, which divides directly into two. The various types of nuclear division in Protozoa have been classified as promitosis, mesomitosis and metamitosis, for detailed accounts of which those interested must refer to the text-books and original descriptions.

I have dealt briefly with the problem of the evolution of karyokinesis because the process of nuclear division is, in my opinion, of enormous importance in the general evolution of living organisms. I have expressed elsewhere[28] the opinion that the very existence of multicellular organisms composed of definite tissues is impossible until the process of karyokinesis has been established and perfected. For tissue-formation it is essential that all the cells which build up any given tissue should be similar, practically to the point of identity, in their qualities; and if it is the chromatin-elements of the cell which determine its qualities and behaviour, then the exact qualitative division of the chromatin, as effected in karyokinesis, is indispensable as a preliminary to the production of identically-similar daughter-cells by division of a parent-cell. Hence it becomes intelligible why, amongst Metazoa, we find the occurrence of nuclear division by karyokinesis in its most perfect form to be the rule, and 'direct' division of the nucleus to be the rare exception, while on the other hand, in the Protista, and especially in the Protozoa, we find every possible stage in the gradual evolution of the exact partition of the chromatin in the process of nuclear division, from chromidial fragmentation or the most typical amitosis up to processes of karyokinesis as perfect as those of the Metazoa.

[28] *Op. cit.* p. 120.

There now remains only one point of general interest in the evolution of the cell to which brief reference must be made, namely, the divergence of animal and vegetable cells. Not being a botanist, I desire to approach this question with all caution; but as a protozoologist it seems to me clearly indicated that the typical green plant-cell took origin amongst the Flagellata, in that some members of this group of Protozoa acquired the peculiar chromatophores which enabled them to abandon the holozoic or animal mode of life in exchange for a vegetative mode of nutrition by means of chlorophyll-corpuscles. It is well known that many of these creatures combine the possession of chlorophyll with an open, functional mouth and digestive vacuoles, and can live either in the manner of plants or of animals indifferently or as determined by circumstances. It would be interesting to know exactly what these chromatophores, at their first appearance, represent; whether they are true cell-organs, or whether, as some authorities have suggested, they originated as symbiotic intruding organisms, primitively independent. I do not feel competent to discuss this problem. I would only remark here, that if the green plant-cell first arose amongst the Flagellata, then the distinction between plant and animal (that is, green plant and animal) is not so fundamental a divergence in the series of living beings as is popularly supposed, but is one which did not come into being until the evolution of organisms had reached a relatively advanced stage, that, namely, of the true nucleated cell.

I have confined myself in this address to the evolution of the cell as this organism is seen in its typical form in the bodies of the multicellular organisms, starting from the simplest conceivable type of living being, so far as present knowledge enables us to conceive it. But there is not the slightest reason to suppose that the evolution of the Protista took place only in the direction of the typical cell of the cytologist. Besides the main current leading up to the typical cell there were certainly other currents tending in other directions and leading to types of structure very unlike the cells composing the bodies of multicellular organisms. It is impossible that I should do more here than indicate some of the divergent lines of evolution, and I will confine myself to those seen in the Protozoa.

Taking as the starting-point and simplest condition in the Protozoa a simple cell or protocyte, in which the body consists of a small mass of cytoplasm containing a nucleus, with or without chromidia in addition, an early specialisation of this must have been what I may term the plasmodial condition, typical of Rhizopods, in which the cytoplasm increased enormously to form relatively large masses. The nucleus meanwhile either remains single and grows very large or, more usually, a great number of nuclei of moderate size are formed. From this large plasmodial type is to be derived the foraminiferal type, characterised by the creeping habit of life, and probably also the radiolarian type, specialised for the floating pelagic habit. Both foraminiferal and radiolarian types are characterised by an excessive development and elaboration of skeletal structures, and the geological record proves that these two types of organisms attained to a high degree of specialisation and diversity of form and structure at a very early period.[29] The Mycetozoa exemplify another development of the creeping plasmodial type adapted to a semi-terrestrial mode of life.

In the Mastigophora the body generally remains small, while developing organs of locomotion and food-capture in the form of the characteristic flagella. In this class there is a strong tendency to colony-formation brought about by incomplete separation of sister-individuals produced in the ordinary process of reproduction by binary fission. The so-called colonies (they would better be termed families) show a most significant tendency to individualisation, often accompanied by physiological and morphological specialisation of the component flagellate individuals.

As an offshoot, probably, from ancestors of the Mastigophoran type arose the Infusoria, the Ciliata and their allies, representing by far the most highly-organised unicellular type of living being. No cell in the bodies of the Metazoa attains to such a complication of structure as that exhibited by many

[29] For Foraminifera see especially Heron-Allen, *Phil. Trans.* (B), vol. 206 (1915), p. 229.

Ciliates. In the Metazoa the individual cells may be highly specialised for some particular function of life; but a Ciliate is a complete and independent organism and is specialised for each and all of the vital functions performed by the Metazoan body as a whole. From the physiological standpoint a Ciliate (or any other Protist) is equivalent and analogous to a complete Metazoon, say a man, but I cannot for a moment agree with Dobell [30] that the body of a Ciliate is homologous with that of a Metazoon—not at least if the word homologous be used in its usual biological sense of homogenetic as opposed to homoplastic. Dobell appears to me to negative his own conclusion when he maintains that the body of a Ciliate is 'non-cellular' while admitting that the Metazoon is multicellular; how then can they be said to be homologous? Only if the term homologous be used in a sense quite different from its ordinary significance.[31]

In addition to the highly-developed structural differentiation of the body the Infusoria exhibit the extreme of specialisation of the nuclear apparatus in that they possess, as a rule, two distinct kinds of nuclei, micronuclei and macronuclei, composed respectively of generative and trophic chromatin, as already pointed out. This feature is, however, but the culminating point in a process of functional specialisation of the chromatin which can be observed in many Protozoa of other classes, and which, moreover, is not found invariably in its complete form in all Ciliata.

In this address I have set forth my conceptions of the nature of the simplest forms of life and of the course taken by the earliest stages of evolution, striving all through to treat the problem from a strictly objective standpoint, and avoiding as far as possible the purely speculative and metaphysical questions which beset like pitfalls the path of those who attack the problem of life and vitalism. I have, therefore, refrained as far as possible from discussing such indefinable abstractions as 'living substance' or 'life,' phrases to which no clear meaning can be attached.

How far my personal ideas may correspond to objective truth I could not, of course, pretend to judge. It may be that the mental pictures which I have attempted to draw are to be assigned, on the most charitable interpretation, to the realm of poetry, as defined by the greatest of poets, rather than of science.

> 'The lunatic, the lover and the poet
> Are of imagination all compact;
> . . . . . .
> And as imagination bodies forth
> The forms of things unknown, the poet's pen
> Turns them to shapes and gives to airy nothings
> A local habitation and a name.'

If I might be permitted to attempt an impartial criticism of my own scheme, I think it might be claimed that the various forms and types of organisms in my evolutionary series, namely, the simple cell or protocyte, the cytode or pseudomoneral stage, the micrococcus, even the biococcus, are founded on concrete evidence and can be regarded as types actually existent in the present or past. On the other hand the *rôle* assigned by me to each type in the pageant of evolution is naturally open to dispute. For example, I agree with those who derive the Bacteria as primitive, truly non-cellular organisms, directly from the biococcus through an ancestral form, and not at all with those who would regard the Bacteria as degenerate or highly-specialised cells. But the crux of my scheme is the homology postulated between the biococcus and the chromatinic particle—chromidiosome or chromiole—of true cells. In support of this view, of which I am not the originator, I have set forth the reasons which have convinced me that the extraordinary powers and activities exhibited by the chromatin in ordinary cells are such as can only be explained on the hypothesis that the ultimate chromatinic units are to be regarded as independent living beings, as much so as the cells composing the bodies of multicellular organisms; and, so far as I am concerned, I must leave the matter to the judgment of my fellow-biologists.

[30] *Journal of Genetics*, iv. (1914), p. 136.
[31] See Appendix A.

I may point out in conclusion that general discussions of this kind may be useful in other ways than as attempts to discover truth or as a striving towards a verity which is indefinable and perhaps unattainable. Even if my scheme of evolution be but a midsummer-night's fantasy, I claim for it that it co-ordinates a number of isolated and scattered phenomena into an orderly, and, I think, intelligible sequence, and exhibits them in a relationship which at least enables the mind to obtain a perspective and comprehensive view of them. Rival theories will be more, or less, useful than mine, according as they succeed in correlating more, or fewer, of the accumulated data of experience. If in this address I succeed in arousing interest and reflection, and in stimulating inquiry and controversy, it will have fulfilled its purpose.

Appendix A.—*The Cell-Theory.*

The most recent attack on the Cell-theory, as it is understood by the majority of modern biologists, has been made by Mr. Dobell, who, if I understand him rightly, refuses to admit any homology between the individual Protistan organism and a single cell of the many that build up the body of a Metazoon. On the contrary, he insists that the Protist is to be regarded as homologous with the Metazoan individual as a whole. On these grounds he objects to Protista being termed 'unicellular' and insists that the term 'non-cellular' should be applied to them.

As regards the cellular nature of the Protista, it is one of my aims in this address to show that amongst the Protista all stages of the evolution of the cell are to be found, from primitive forms in which the body cannot be termed a cell without depriving the term 'cell' of all definable meaning, up to forms of complex structure in which all the characteristic features of a true cell are fully developed. Thus in the Protozoa we find the protoplasmic body differentiated into nucleus and cytoplasm; the nucleus in many cases with a structure comparable in every detail to that of the nucleus of an ordinary body-cell in the Metazoa; reproduction taking place by division of the body after a karyokinetic nuclear division often quite as complicated as that seen in the cells of the Metazoa and entirely similar both in method and in detail; and in the sexual process a differentiation of the gametes on lines precisely similar to those universal in Metazoa, often just as pronounced, and preceded also in a great many cases by phenomena of chromatin-reduction comparable in principle, and even sometimes in detail, with the reduction-processes occurring in Metazoa. I really feel at a loss to conceive what further criteria of homology between a Protozoon and a Metazoan cell could be demanded by even the most captious critic. On the ground of these and many other similarities in structure and behaviour between the entire organism in the Protozoa and the individual cell, whether tissue-cell or germ-cell, in the Metazoa, the case seems to me overwhelmingly convincing for regarding them as truly—that is to say, genetically—homologous.

Looking at the matter from another point of view, namely, from the standpoint of the Metazoa, it is true that in the groups of most complicated and highly organised structure the cells often develop secondary connections or fusions due to incomplete division, to such an extent that in parts of the body the individuality of the primitively distinct cells may be indicated only by the nuclei (as may occur also in Protozoa, for example, in associated gregarines); but in all Metazoa certain of the cells retain permanently their complete independence and freedom of movement and action. In the Metazoa possessing the simplest and most primitive types or organisation, such as sponges and cœlenterates, the cells composing the body show far greater independence of action, and in the course of ontogeny entire groups of cells may alter their relative positions in the body as the result of migrations performed by individual cells; while it is now well known that if the adult sponge or hydroid be broken up completely into its constituent cells, those cells can come together again and build up, by their own individual activity, the regenerated body of the organism. For these reasons it seems to me impossible to regard the body-cells of the Metazoa otherwise than as individual organisms complete in themselves, primitively as independent as the individual Protozoon, and in every way comparable to it.

From the considerations summarised very briefly in the two foregoing para-

graphs and capable of much greater amplification and elaboration, the view generally held that the entire organism of a Protozoon is truly homologous with a single body-cell of a Metazoon seems to me quite unassailable, and to have gained in force greatly from recent investigations both upon Protozoa and Metazoa. On the other hand, any Protist, as an organism physiologically complete in itself, is clearly analogous to the entire individual in the Metazoa —a comparison, however, which leaves the question of genetic homology quite untouched.

As regards the application of the term unicellular or non-cellular to the Protozoa, it is evident that if the evolution of living beings had never proceeded beyond the stage of the Protista, and if no multicellular organisms had ever been evolved, the term cell could then never have been invented by an intelligent being studying other living beings, supposing for an instant the possibility of such intelligence existing apart from a mammalian brain. So long as the Protozoa are studied entirely by themselves, without reference to any other forms of life, they may be termed non-cellular in the sense that they are not composed of cells. It is only when they are compared with multicellular organisms that the term unicellular becomes applicable on the ground of the homology already discussed between the Protozoon and the body-cell of the Metazoon.

The following Papers and Reports were then read :—

1. *The Future of Scientific Literature in relation to the War.* *By* Professor A. Meek.

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2. *Report on the Occupation of a Table at the Zoological Station at Naples.*—See Reports, p. 148.

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3. *Report on the Biological Problems incidental to the Belmullet Whaling Station.*—See Reports, p. 124.

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4. *Report on the Nomenclator Animalium Generum et Sub-generum.* See Reports, p. 147.

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5. *Report on the Biology of the Abrolhos Islands.*- See Reports, p. 148.

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6. *Report on the Collection of Marsupials.*—See Reports, p. 147.

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7. *Report on the Occupation of a Table at the Marine Laboratory, Plymouth.*—See Reports, p. 149.

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8. *Materials for a Graphic History of Comparative Anatomy.* *By* Professor F. J. Cole *and* Nellie B. Eales, *B.Sc.*

A few years ago one of us attempted to apply graphic methods to an historical study of anatomical museums.[1] The results were encouraging but not conclusive, since the number of such museums which could be traced (537) was too small to admit of adequate treatment by statistical methods. It then occurred to us to make a similar attempt on the literature of comparative anatomy generally, in the hope that, with a much greater bulk of records to juggle with, we might succeed in conjuring form and precision out of an

[1] Cp. Cole, *The Mackay Miscellany*, p. 302, Liverpool, 1914.

amorphous mass of data. Our object was a threefold one: (1) to represent by a curve the activities of comparative anatomists year by year from the sixteenth century to 1860; (2) to separate out the performances of each European country; (3) to determine which groups of animals and what aspects of the subject engaged the attention of workers from time to time. In other words, it seemed possible to reduce to geometrical form the activities of anatomists as a whole, and the relative importance in time and interest of each country and subject. We do not propose in this preliminary note to dwell on the difficulties of the work—they have been numerous, and relate chiefly to the difficulty in assigning certain workers to their appropriate countries, and in making due allowance for others whose output has been disproportionate to the influence they have exercised.

For the period between the years 1543 and 1860 we have made records of 6,304 papers which deal wholly or partly with the anatomy of animals, as apart from those having a systematic interest only. It is inevitable that we have missed many, but the number can hardly bear any serious proportion to those we have recorded. In Fig. 1 each division in the horizontal direction represents fifty years, and the height of the chart in any year represents the number of papers published in that year. In assigning a paper to any particular year we have had to consider whether the date of publication bears a close relation to the completion of the work. In some cases publication may be many years subsequent to the death of the author, and our method has been to chart the actual or approximate year in which the work was finished rather than the date of publication. At the same time we feel that the date of publication does stand for something—it represents at least a current interest in the subject of the research. We give four specimen charts (Figs. 1-4), selected from the number that have been made.

An examination of Fig. 1 shows that only intermittent research was carried on before the year 1650, but that in the next fifty years there was considerable activity, culminating at about 1683, and thereafter subsiding. There is no doubt that this sudden revival was due almost exclusively to the Academia Naturæ Curiosorum founded in 1652, the Royal Society of London (1660), the French Academy of Science (1666), and, to a much less extent, the Collegium Anatomicum of Amsterdam (*c.* 1665). From 1700 to 1750 work is steadily maintained, but at a lower numerical level, and the second revival begins at 1750, gradually increases in volume up to 1800, and then suddenly swings up to a very high maximum between 1835 and 1840, finally declining somewhat considerably down to 1860, beyond which we have collected no data.

If now we consider the achievements of individual countries, we find that the second revival was initiated by France (Fig. 2), followed closely by Germany (Fig. 3), and at some distance by England (Fig. 4). The last country, however, reaches her maximum first, then Germany, and finally France. Having passed the maximum point, France progressively declines up to 1860, but both England and Germany, having reached their lowest point by 1850, show signs of recovery. It should be stated that Holland and Denmark take a distinct part in the seventeenth-century revival, and that Italy is undoubtedly concerned in initiating the similar movement in the nineteenth century. Germany claims 2,066 records, France 1,507, England 1,171, Italy 373, Holland 214, Switzerland 170, and Denmark 155.

An analysis of authorities shows in England the Hunterian school in splendid isolation—an example which was not driven home until, more than thirty years after the death of Hunter, Owen published his first anatomical paper. In France, on the other hand, the work of Buffon, Vicq d'Azyr, and Cuvier is promptly and steadily followed up. Germany is almost devoid of pioneers in the eighteenth century, but her record from 1800 includes an almost unbroken succession of well-known workers, and it is this solidarity which makes the German chart so impressive. England claims fifteen writers with a minimum of ten papers to their credit, Germany 39, and France 35. The most voluminous writers on comparative anatomy have been Owen, Home, G. St. Hilaire, J. Müller, Dufour, Rathke, Duvernoy, Cuvier, Meckel, Blainville, Milne Edwards, Hyrtl, and Brandt. The earlier writers were very largely Italian, but from 1650 onwards Denmark, England, France, Germany, Holland, and Switzerland successively enter the field.

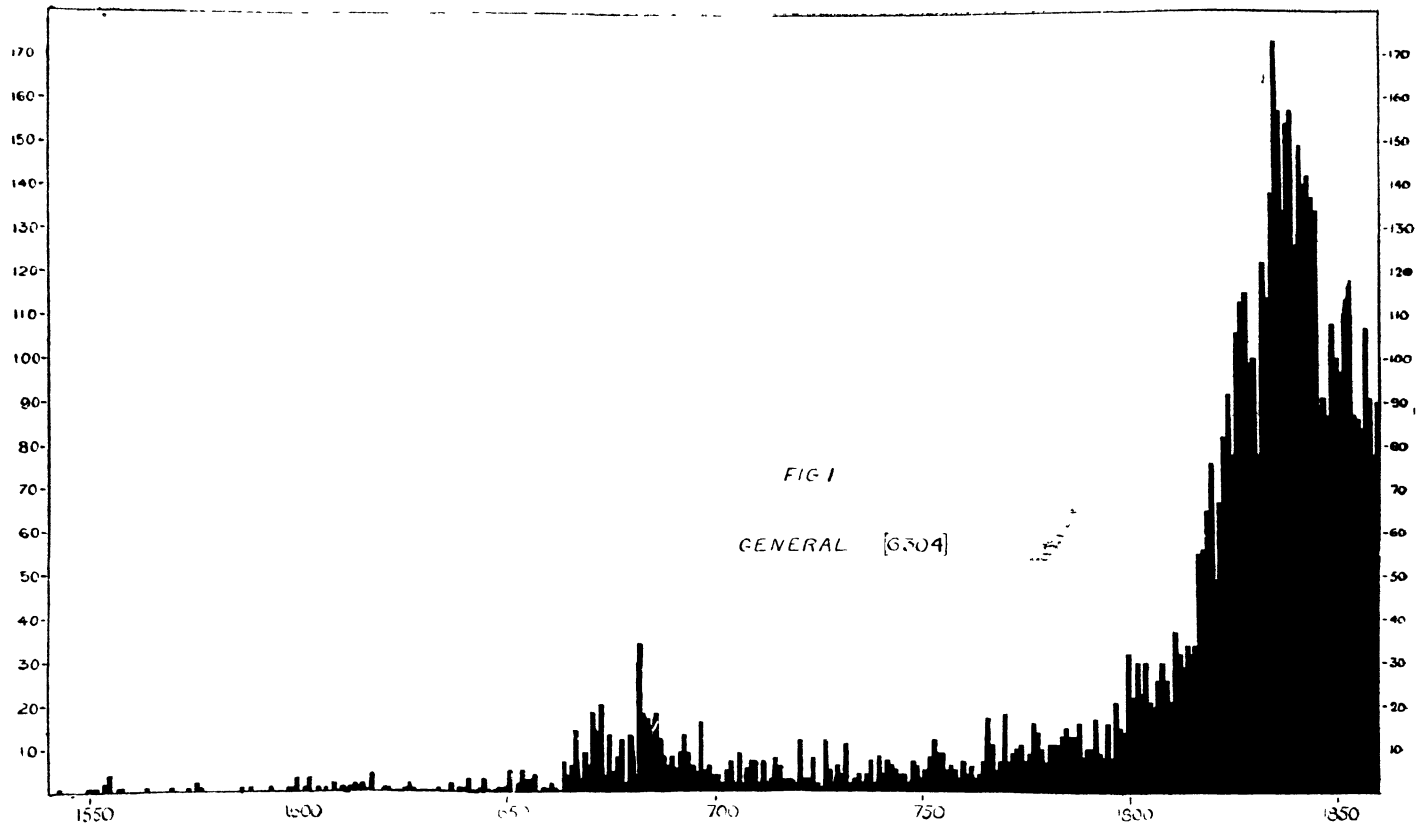


FIG 1

GENERAL [6504]

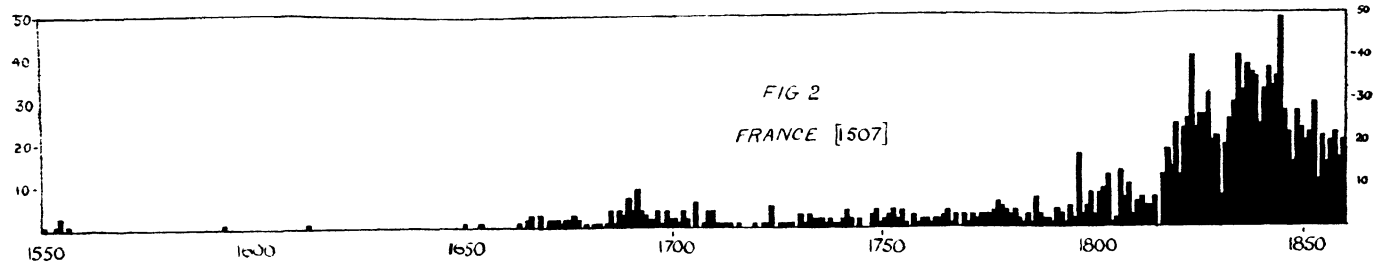


FIG 2

FRANCE [1507]

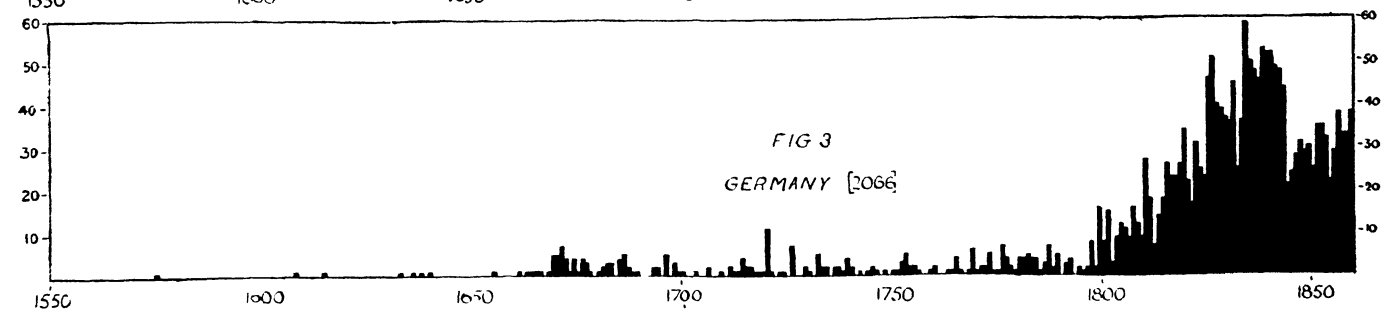


FIG 3

GERMANY [2066]

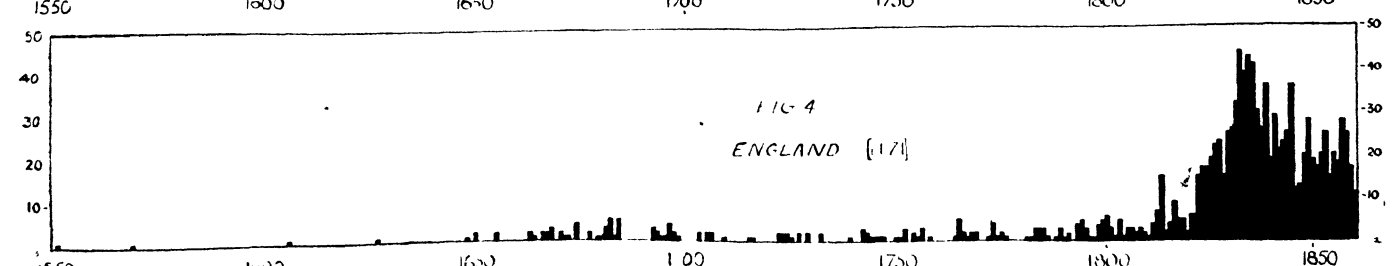


FIG 4

ENGLAND [171]

H H 2

As regards the subjects of study, work has been distributed as follows: Mammals (1,569 papers); Arthropods (863); Fishes (730); Organography (594); Birds (527); Molluscs (388); Worms (357); Reptiles (334); Amphibia (233); Cœlenterates (200); and Echinoderms (62). Of works of a general or more encyclopædic nature there are 471. The seventeenth-century revival related chiefly to Mammals, but concerned to a lesser extent Birds, Fishes, and Arthropods, and to a slight extent Reptiles and Molluscs. In the nineteenth-century revival, Mammals, Arthropods, Fishes, and Organography, in the order mentioned, play the leading part, followed by Birds, Molluscs, and Reptiles. Even in the first half of the eighteenth century, the slackest period since the seventeenth-century revival, interest in the anatomy of Mammals is well maintained.

Each of the Figs. 1-4 shows a certain periodicity of output, especially during the nineteenth century. Roughly speaking, the periods are equal ones of about ten years each. In other words, for each decade there is a rise and fall. This periodicity is well marked in the graph for Germany.

It is not always possible to compare visually the relative bulk of publications at stated intervals, owing to the fact that a large number of works for one year give undue prominence to that period. In order to make comparisons of this kind more readily, graphs have been prepared which show the rise and fall by obtaining the aggregate of the publications for successive periods of five years each and plotting the average.

If Fig. 1 be compared with the graph illustrating the history of Zoological Museums already published, it will be noted that in the latter the seventeenth-century revival is not represented, but that between 1747 and 1770 the influence of Linnæus and Buffon produced an effect which would naturally be wanting in an anatomical graph. The nineteenth-century revival, however, is also to be found in the museum graph. The period lies between 1809 and 1847, and curiously enough the maximum occurs in exactly the same year as in the anatomical graph, viz., 1835.

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9. *The Insect Association of a Local Environmental Complex.* *By* Alfred E. Cameron, *M.A., D.Sc., M.Sc.*

An association is a group of animals uniform over a considerable area, and its unity is dependent upon the migration of the individuals from one stratum to another at different times of day, or at different periods of their life-histories.

The environment is a complex of many factors, each dependent upon another or upon several others. A change in any one effects changes in one or more others. The most important environmental factors are water, atmospheric moisture, light, temperature, pressure, oxygen, carbon dioxide, food, enemies, materials used in abodes. In nature the combinations of these requisite for the abode of a considerable number of animals are called 'environmental complexes.' Local complexes are often referred to as secondary or minor conditions or as *edaphic* or soil conditions.

It is very probable that the plant and animal associations will prove to be co-extensive.

In the study of an insect association one has a choice of two methods: (1) One may treat of a species, genus, family, or order as one's unit and show the relation of each one severally to the environment. (2) The other method, which is more comprehensive, treats the whole of the environmental factors as a single entity to which all of the insects of the various orders respond in unison. The latter was the method adopted by the author.

The physiography and topography of the district, Holmes Chapel, Cheshire, were reviewed in a general way and the geological facts summarised. Such a proceeding is necessary because the plant association, so important in relation to insect life, is largely determined by the nature of the soil of the district as well as the exposure and other factors. The vegetation of the Holmes Chapel area is mesophytic, and the plant association is of the grassland mixed wood type.

Records of barometric pressure, air temperature, and soil temperature were kept for the period during which the work lasted. In many cases it is difficult

to say what is the direct influence of any one physical factor on the insect association, but it is hoped by making a study of an entirely different area to reach important conclusions by the method of comparison. Probably it will be found that the best index of the physical factors of an environment may be derived from the 'evaporating power of air' as measured by the porous cup atmometer.

The index of an insect's habitat is where it breeds, which may not be the place where it feeds. Many insects migrate from one vertical stratum to another at different periods of their life-histories or according as they are actuated by their various needs. Some insects are peculiar to an association, others invade from adjacent associations. An analysis of their habits, which involves a knowledge of their larval habits, enables one to relegate them to their proper association. A tabular statement of these facts has been presented in the paper, and the various orders of Apterygota, Plecoptera, Neuroptera, Mecoptera, Trichoptera, Diptera, Coleoptera, Lepidoptera, Hymenoptera, and Hemiptera as specifically determined have been reviewed.

A soil insect-census of two different grasslands in the association, differing in their soil-types and vegetational covering, showed that in any given locality the soil-insect fauna of grassland is not likely to vary to any great extent. For a determination of the faunistic differences on the basis of the variation of edaphic factors, a very thorough analysis is necessary.

10. *Exhibition of Lantern Slides of Maps illustrating Tertiary Changes, according to Geologists, in the Northern Hemisphere, and the Light thrown on the Subject by a Comparison of Maps showing Distribution of Fish.* By Professor A. MEEK.

THURSDAY, SEPTEMBER 9.

The following Papers were read :—

1. *Discussion on the Relation of Chromosomes to Heredity.—Opened by* Professor E. W. MACBRIDE, *F.R.S.*

There seems to be no escape from the position that the chromatin viewed as a whole is the bearer of the hereditary tendencies, for the influence of the father in determining the character of the offspring is as potent as that of the mother. Now the head of the spermatozoon is the only part of the father which enters into the constitution of the progeny, and this appears to consist practically exclusively of chromatin (Duesberg). This chromatin appears after fertilisation in the somatic nuclei of the embryo as a group of chromosomes, which are in many cases distinctly separable into two sub-groups of maternal and paternal chromosomes respectively. These can only influence the characters of the embryo by emitting substances which pass through the nuclear membrane into the cytoplasm. The formation of the organs of an embryo is known in many cases to be due to substances localised in the cytoplasm. But the formation of these substances can be shown to be due to chromatic emission from the nucleus of the unripe egg (Schaxel), and in many cases where the fertilised egg exhibits marked cytoplasmic differentiation the cytoplasm of the unripe egg can be shown to be of homogeneous composition (Boveri). Driesch has shown that in some cases the nuclei of an embryo can be displaced from their positions without altering the mutual relations of the organs of an embryo. From this it is argued that the nuclei are all alike and indifferent. But during this period the embryo is of uniform character, *i.e.*, all its parts are equipotential. When this period has passed, and definite localisation of the rudiments of organs begins, this is associated with renewed emission of chromatin into the cytoplasm (Schaxel).

Whether individual chromosomes are the bearers of different characters or

groups of characters is a question difficult to decide. The experiments of Wilson and his school on *Drosophila* and other insects suggest that they are. The best instance is the so-called sex-chromosome, which is supposed to carry the determiner of sex and of the qualities which are sex-limited. In some cases the female nucleus possesses one more chromosome than the male, and there are two kinds of spermatozoon, one with one more chromosome than the other. Hence it is assumed that sex is fixed by the spermatozoon. But when two species are crossed, differing in a secondary sexual character, the distribution of this character in the hybrid and in the F_2 generation shows that it cannot possibly be carried by the sex-chromosome. Moreover, in other cases (*Abraxas*) the inheritance of characters in a cross between two varieties indicates that there are two kinds of egg and one kind of spermatozoon. Yet no constant chromosomal difference between the two kinds can be detected (Doncaster). In other words, the odd chromosome may not be the cause of sex-difference, but in itself the result of that sex-difference.

The phenomena of meiosis, however, and their agreement in form with the sort of segregation of qualities postulated by the Mendelian hypothesis, suggest very strongly that determiners of various characters are situated in definite pairs of chromatin units which become separated from one another at the meiotic division. Since, however, the number of allelomorphic characters can in many cases be proved to be very much larger than the number of chromosomes, the individual chromosomes cannot represent these determiners. May not the chromosomes be simply groups of these determiners adhering by mutual chemical affinity under the peculiar chemical conditions obtaining in the cell in the period preceding karyokinesis? If this be the case, the apparent total disappearance of chromosomes during the resting period could be accounted for.

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2. *The Discession of the Chromosomes and Mitokinetism.*

By Professor Marcus Hartog, *D.Sc.*

In previous papers the author has shown that the phenomena of the cell-spindle may be interpreted as the expression of a field of dual force, centering on the centrosomes as *opposite* poles, on the assumption that the achromatic fibres are more permeable to the force than their surroundings, and lie along the lines of force whose distribution they, of course, modify. The chromosomes are also more permeable, and may be termed '*flexible inductors.*' All objections that have been urged to this view have been shown to be based on neglect either of accepted physical truths or of the realities of the field. But he was so far unable to produce any adequate explanation of the discession of the chromosomes. This deficiency was due to the omission to take note of the different behaviours of isolated *poles* and of *inductors*. The former move along the lines of force; but not the latter, and their path in a uniform field had not yet been worked out by the physicist save in very few, simple, cases. With the collaboration of Mr. Philip E. Belas this problem has received an experimental solution, which is demonstrated at this meeting before Section A. Undoubtedly the path of an inductor in a *uniform* field does not correspond with that of a chromosome in the cell; but the cell-field is *not uniform*, for it is traversed by the spindle-fibres, stretching from pole to pole along the lines of force, and modifying their distribution, as above stated. If we represent these in a magnetic field by pieces of soft iron extending from pole to pole, we see at once that lines of force converge to them on either side, their density increasing as we approach the poles. Now, an inductor tends to move in the direction in which it will include the maximum number of lines of force; and in our models we find indeed that a floating inductor will move along the iron representative of the spindle-fibre. Thus the path of the chromosome is now seen to be in accordance with theory.

The separation of the sister-chromosomes at the equator is difficult to understand if the field be uniform, for the force tending to separate two adjacent inductors lying across the equator is indefinitely small; again here the model shows us how the force is modified by the presence of the achromatin fibre. For the lines of force from either pole are continuous through the inductors in the uniform field; but with the representative of the inductor stretching from pole

to pole, either chromosome transmits at its equatorial end to its sister only *part* of the lines it receives at its polar end, a proportion of them being attracted (or 'refracted') into the fibre.

Such problems, which are too complex to lend themselves to mathematical analysis, can alone be settled by the method of physical experimentation, and the interpretation must needs follow the observation. It is only, indeed, by these last experiments that the problem of the working of the cell-figure has received an adequate explanation on the mitokinetism theory.

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3. *A Statement upon the Theory and Phenomena of Purpose and Intelligence exhibited by the Protozoa, as illustrated by Selection and Behaviour in the Foraminifera.* *By* E. HERON-ALLEN, *F.L.S., F.Z.S., F.R.M.S.*

The author seeks to make the position which he has taken up in this matter definite, and to state the limits beyond which at present he is not prepared to go. He postulates :—

(i.) That every living organism having a separate and independent existence of its own is endowed with that measure and quality of the faculties of Purpose and Intelligence which are adapted to, and called forth by, the individual needs of that organism.

(ii.) That these faculties are illustrated by the utilisation by certain Protozoa (Foraminifera) of foreign substances, selected by the animal from a large heterogeneous mass of environmental adaptable material, and utilised in such a manner as to provide the animal with means (*a*) of adaptation to its special environment, and (*b*) of defence against its known and special enemies.

(iii.) That it is not competent for a consistent evolutionist to postulate a break in his evolutionary cycle (which must, *ex hypothesi*, be continuous) for the introduction at some arbitrary point of an unknown influence of unknown origin to which he gives the name of Intelligence, upon which Purpose depends.

(iv.) That the phenomena to which he has called attention have no relation to, and are not to be confounded with, adaptations or tropisms, and he is not to be interpreted as having made any claims based upon any such confusion.

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4. *The Explanation of Secondary Sex Characters as Characters of Abandoned Function, with Observations on the Insufficiency of the 'Hormone' Theory.* *By* F. W. ASH.

Male secondary characters are not otherwise unique; on the contrary, the character may be bisexual (specific), unisexual, or wholly rudimentary, according to species.

The problem is—why are certain somatic characters, not essentially sex-distinguishing, sex-limited in particular species? No explanatory theory can suffice that does not answer that question.

The selection theory fails to explain why the dimorphism is not neutralised by biparental heredity; while the 'hormone' hypothesis does not account for the particular form assumed by the secondary character.

Male secondary characters cannot well represent (as some have held) a first stage in the evolution of structures that are to be afterwards extended to the other sex; such a view entails such inconsistent assumptions as that newly evolving organs tend to over-develop in males while still incapable of appearance in females and young, and yet may at the same time be rudimentary (not incipient) in the two latter; or that archaic and general characters (such as the canine tooth) are still being independently evolved in divers widely separated types.

The 'hormone' theory, apart from the insufficiency before mentioned, implies an artificial ontogenetic distinction between the same organs in allied species; for example, between the tusk of the Indian and that of the African elephant; or between similar tissue in different parts of the same animal (as between certain feathers in a bird and the other feathering).

I suggest that the real explanation of male secondary characters is that they are characters of abandoned function or their physiological equivalents—suppressed in the young in favour of more essential growth (of organs still fully functional), and in the adult female because, with her, nutritive surplus is more directly diverted to the purposes of reproduction. Hence such characters usually only find opportunity for full expression in adult males.

Where an organ is in process of retrogression through loss of function, an intermediate stage of extravagant growth under favourable nutritive conditions may occur before the wholly rudimentary stage is reached.

Secondary sex exaggerations may significantly parallel enlargements due to accidental loss of function. The tusk of the male babirussa may be compared with instances of occasional circular overgrowth in the tusk of the hippopotamus, or with the elongation of a rodent's incisor when the opposing tooth is lost.

The dependence (usual amongst vertebrates) of the development of the secondary character on the active presence of the male gonad may, perhaps, be explained by reference to the phenomena of periodicity.

Through inherited correlation, the activity of the gonads influences the nutritive bias in the direction of reproduction, the related physiological 'ebb and flow' being on an enlarged or more cataclysmic scale, as it were, and so affording latent characters opportunity for expression (in males). This suggestion is rather supported by the fact of the renewal of the secondary feature at the breeding season in various types.

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5. *Studies on the Biology of the Appendix Vermiformis in Monotremes and Marsupials.* By WILLIAM C. MACKENZIE, *M.D.*

The following animals were considered : Monotremata : Ornithorhynchus and Echidna; Marsupialia : Phascolarctos, Phascolomys, Dasyurus, Macropodidæ, and Trichosurus.

Attention was drawn to the fact that one Monotreme (Ornithorhynchus) has a cæcum and the other (Echidna) a true vermiform appendix comparable, macroscopically and histologically, to that of man, ape, and wombat—the three mammals regarded as having a true vermiform appendix. Various grades of degeneration in the appendix of Echidna were demonstrated. Amongst the Macropodidæ, the wallaby and the kangaroo exhibited a well-marked difference in the cæcal region. In Phascolomys the appendix was shown to have reached a much more advanced degree of degeneration than that of man—even to complete disappearance. The mode of disappearance is by incorporation in the wall of the ileum, and of this the various gradations were shown. This animal, then, presents suggestive evidence of the mode of the further degeneration of man's appendix. No cases of inflammation of the cæcal region have been met with amongst the Phascolomyidæ.

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6. *Regeneration of the Tail in the Common Lizard* (L. vivipara) *after Autotomy.* By CHARLES POWELL WHITE.

The lizards which form the basis of these observations were found under natural conditions in North Wales.

Autotomy takes place through the middle of a vertebra. There is no special autotomy-site as in the legs of crabs, but apparently any vertebra may be involved. Regeneration may continue until the regenerated tail is fully as long as the original one.

In such a fully regenerated tail are found :

1. The skin and subcutaneous tissue. 2. The muscles situated beneath the skin to which they are attached. They consist of sixteen longitudinal bundles and are also segmented transversely in zig-zag rings, each segment apparently corresponding to a ring of scales in the skin. 3. Beneath the muscles is a layer of fatty connective tissue in which run nerves and blood-vessels. All the nerves are derived from the last three pairs of nerve roots in the stump of the

tail. There are twenty-four main trunks in all, four branches from each nerve. The blood-vessels are derived from the caudal aorta and vein. Lymphatics are also found. The main trunks of the sympathetic which accompany the aorta can be traced for some distance into the regenerated tail and send branches to the different blood-vessels. No new ganglia are formed. 4. In the centre of the tail is a tube of cartilage, unsegmented and continuous except for some perforations through which blood-vessels pass to the interior. This tube is continuous with the body and neural arches of the vertebra through which the fracture has taken place. 5. In the cartilage tube is an epithelial tube continuous with the central canal of the spinal cord.

On examining tails in various stages of regeneration we find the following: The wound after autotomy is quickly covered with new skin beneath which is a mass of spindle cells which apparently originate in the connective tissue. This cellular mass acts as a growing point to the new tail, and from it the various structures are developed. The cartilage, fat, and blood-vessels arise by differentiation from the spindle cells. The muscle fibres arise segmentally in groups, the groups nearest the tip being the least differentiated. The muscles in the stump play no part in the process.

The nerve trunks involved in the autotomy-wound elongate as the regeneration proceeds. The corresponding posterior root ganglia are increased in size or number owing to increase in size of the nerve bundles. There is no increase in size or number of the ganglion cells.

The central canal reaches to the extreme tip of the tail just beneath the skin. It there loses itself in the surrounding cells and is apparently developed from them. It has no connection with the epidermis.

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7. *The Geographical Distribution of the* Pennatulacea. *By* Professor S. J. Hickson, *F.R.S.*

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8. *Exhibition of Specimens in the Zoological Laboratories of the University.*

FRIDAY, SEPTEMBER 10.

The following Papers were read :—

1. *Account of the Plankton collected during Traverses of the Great Oceans on the journey to Australia and back, by several routes, in 1914.* *By* Professor W. A. Herdman, *F.R.S.*, *and* Andrew Scott, *A.L.S.*

Advantage was taken of the meeting of the British Association in Australia last summer to obtain samples of surface plankton collected continuously during traverses of the North and South Atlantic, the Southern Ocean, the Indian Ocean, the seas of the Malay Archipelago, and the Pacific. The method of collecting was that made use of by one of us on several previous occasions, and which consists briefly in letting the sea-water which is pumped continuously into the ship flow out from a bath- or other tap through a fine-meshed silk net, which is changed morning and evening—so that each sample obtained represents a twelve hours' catch, either day or night. The silk used was No. 20 of Dufour's series, having about 6,000 meshes to the square centimètre.

Small samples of each gathering were examined somewhat rapidly with the microscope while fresh, and any special organisms and colours were noted. The whole was then preserved in a solution of formalin.

The outward voyage on the Blue Funnel liner *Ascanius* was by the Cape route, so that the 72 samples collected represent a traverse from Liverpool

down the North and South Atlantic by the Canary Islands along a roughly north and south line to Cape Town, and from thence along the Southern Ocean on an east and west line to Fremantle in Western Australia. The managers of the Blue Funnel line (Messrs. Alfred Holt & Co.) materially promoted this work by most generously fitting up special discharge pipes with large taps on both sides of the top deck, and by fitting up a large deck cabin on the *Ascanius* as a laboratory for Professor Herdman, in which microscope work could be conveniently carried on either by day or electric light.

On the return journey three observers took part in the work. Professor Herdman took a series of 32 samples through the Indian Ocean and Red Sea, Dr. A. Holt collected 42 samples during parts of his homeward route by the Malay Archipelago, Hong Kong, Singapore, and Ceylon; and Mr. P. G. Bailey obtained for us 21 samples during his voyage by New Zealand across the Pacific to San Francisco. We are very much obliged to Dr. Holt and Mr. Bailey for this kind assistance.

In addition to these 167 samples collected from most of the great oceans of the world in the summer of 1914, we have also taken into consideration a few former collections made by one of us, viz., (1) on a traverse to and from Cape Town by the Atlantic route in 1905, (2) on a traverse of the Red Sea and Indian Ocean to and from Ceylon in 1907, and (3) two or three other minor collections which may be useful in filling up gaps between the larger series.

The samples are now being examined systematically and exhaustively, and it will be some time yet before we can make a detailed report; but we think it may be of interest to give now this preliminary account of the matter.

So far as possible the conditions of collecting were kept constant, so that the samples might be comparable with one another. It was calculated that during the work on the *Ascanius* the amount of water running through the net was about 10 litres per minute or 7,200 litres per twelve hours' gathering. If we attempt to compare this volume of water strained with the amount that passes through an ordinary horizontal or vertical plankton net of 34 cm. diameter at the mouth we think it might on a rough approximation be the equivalent of 100 yards of horizontal towing or 50 fathoms in a vertical haul.

On looking at the volumes of the gatherings it is noteworthy how the amount of plankton per haul drops in passing from coastal to oceanic waters. The first gathering was practically across the mouth of the English Channel from the Scilly Isles to abreast of Ushant, and was an ordinary typical English summer plankton measuring 14·5 c.c. and consisting of many of the smaller Copepoda such as *Oithona* and *Pseudocalanus* with a few *Centropages*, and also a considerable number of the Pteropod *Limacina*. The fourth haul, thirty-six hours later, in the Atlantic about the latitude of Lisbon, measured only 1 c.c. and contained, in addition to a few species of the smaller Copepoda, oceanic organisms such as *Globigerina bulloides* and *Acanthometra*.

A drop in the quantity of plankton per haul was noticed in passing from the English Channel to the Bay of Biscay and a further drop in passing out into the Atlantic off the coast of Portugal During the next few days in the open Atlantic north of the Canary Islands the following additional Copepoda were noteworthy in the gatherings: *Clausocalanus arcuicornis, Corycæus rostratus*, and *C. gracilicauda, Calocalanus plumulosus, Microsetella rosea, Oncæa subtilis, Pleuromamma gracile, Lucicutia flavicornis*, and *Sapphirina nigromaculata*.

In the South Atlantic, between the Canary Islands and the Cape, at least three species of *Sapphirina* (*S. nigromaculata, S. Salpæ*, and another) occurred frequently in the gatherings; and other Copepoda that appeared south of the Canaries were: *Pleuromamma gracile* and *P. abdominale, Undeuchæta plumosa, Candacia pachydactyla, C. bispinosa* and *C. bipinnata, Metridia boecki, Undinula vulgaris, Corycæus carinatus, Calocalanus pavo*, and various species of *Macrosetella, Euchæta, Miracia, Pontellopsis, Labidocera*, and others—only the more conspicuous forms are mentioned.

The increase in volume of the catch on approaching Cape Town was well marked—successive hauls being 2, 3, 4, 6·5 and then 11 c.c., and after leaving the Cape they fell again to 5, 6, 6·4 and 4 c.c.

On the day after leaving the Cape (July 13) the sea was very noticeably blood-red in colour, and highly luminous at night. The gatherings were found to contain large numbers of a small red Peridinian which was probably the

cause both of the colour and of the luminosity. On July 17, at night, a fairly large catch was almost wholly composed of *Metridia boecki*.

In the traverse across the Southern Ocean, between July 13 and 28, the more noticeable forms in the plankton were *Macrosetella, Pleuromamma* (two spp.), *Euchæta* (including one species probably new to science), *Mecynocera, Corycæus, Microsetella, Calocalanus, Clausocalanus, Sapphirina* (*S. metallina* and *S. gemma*), and the conspicuous black-coated *Candacia aethiopica*—along with many diatoms and other smaller forms not yet identified.

The volume of the plankton again increased on getting into the Australian coastal waters. For example, on August 2, in Spencer Gulf, we had quite a large catch of smaller Copepoda—chiefly *Microsetella* and *Euterpina*.

It is hoped that the detailed report upon these and the other oceanic traverses will be laid before the Liverpool Biological Society in the course of next winter.

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2. *On Larvæ of* Lingula *and* Pelagodiscus *collected in the Red Sea and Indian Ocean.* *By* J. H. Ashworth, *D.Sc.*[1]

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3. *Notes on Zoological Collecting in Australia with the British Association in 1914.* *By* Professor A. Dendy, *F.R.S.*

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4. *Notes on Insects collected during the Visit of the British Association to Australia in 1914.* *By* Professor E. B. Poulton, *F.R.S.*

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5. *Bionomics of the Genus* Eronia. *By* F. A. Dixey, *F.R.S.*

Eronia is a genus of Old-World Pierine butterflies distributed over the whole of Africa south of the Sahara, and southern Asia with the Malayan islands as far as the Moluccas. It is remarkable for the diversity between the sexes shown by most of the species, and for the fact that in nearly every instance the females bear a strong resemblance to forms belonging to other groups. The genus may be divided under subgeneric headings, as follows: (1) *Nepheronia*, comprising the species inhabiting continental Asia and the Malayan islands; (2) *Leuceronia*, consisting of four or five species which are African and Arabian in distribution; and (3) *Eronia* proper, which includes two species belonging to continental Africa only. In *Nepheronia* the likeness of the females is to various species of Danainæ. In a few cases the females of this section are dimorphic, each such form bearing the aspect of a separate species of Danaine. In *Leuceronia* three of the species have polymorphic females; these in every instance present a copy of some other butterfly belonging to the Pierine sub-family but of no close affinity with *Leuceronia*. One of the remaining species resembles in both sexes a Pierine of a distinct group. The third section or sub-genus, *Eronia* proper, consists of two species, in both of which the underside is coloured like a dead leaf. In addition to this, one of the species is on the upper side almost exactly like another brilliantly coloured Pierine inhabiting the same region. In this case the resemblance is closest in the males.

In the first group, the likeness to Danaines can scarcely be due to affinity; for, besides the fact that the males remain unaffected, there is no near relationship between the sub-families concerned. Nor, in the second group, is the connection close between the polymorphic females of *Leuceronia* and the Pierines which they resemble. The fact that the similar forms inhabit, speaking generally, the same districts suggests a climatal or other local influence; but, besides the difficulty of conceiving the *modus operandi* of such an influence, the polymorphism of many of the females and the unaltered aspect of the males

[1] See *Trans. Roy. Soc. Edin.*, vol. li., pp. 45-69, Pls. iv., v., 1915.

make this unlikely. The 'explanation' offered by Fruhstorfer, viz., that 'the mimics were modified by the same (as yet unknown) influences under which the colouring of the models developed,' is obviously no explanation at all.

Since some of the forms resembled by the *Eronias* are known experimentally, and others are on good grounds believed to be more or less distasteful to insectivorous animals, the theory of mimicry appears to be the most feasible interpretation of the conditions obtaining in this genus.

The likeness between *Eronia leda* and *Teracolus auxo* is somewhat exceptional. The *Eronia* is cryptically coloured beneath; and the resemblance to *Teracolus*, which is strongest in the male, may perhaps be really due to affinity.

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6. *The Relation of the Phylogeny of the Parasite to that of the Host.* By LAUNCELOT HARRISON, *B.Sc.*

The proposition I advance is:—That in the case of total obligate parasites, closely related parasites will be found to occur upon phyletically connected hosts, without regard to other œcologic conditions. As the state of evolution of the parasite will be less advanced than that of the host, it follows as a corollary: That a study of such parasites may give valuable indications as to host phylogeny.

(The following references may be consulted for more detailed statements:—(1) Kellogg, *American Naturalist*, xlvii, p. 129; (2) *ibid.*, xlviii., p. 257; (3) S. J. Johnston, *Rept. Aust. Assn.*, 1913; and (4) *Rept. Brit. Assn.*, 1914; (5) Harrison, *Aust. Zoologist*, 1914, p. 7; and (6) *Parasitology*, viii., p. 88.)

The evidence I shall bring to support the above statements is derived from a study of conditions in the Mallophaga. Kellogg (1) has made a similar statement based on a study of the same group. He has also (2) extended his studies to the Anoplura, and finds that his thesis holds for this order. A striking illustration is the occurrence upon man, upon species of the family Simiidæ, and of the genus *Ateles* alone among the Cebidæ, of the Anopluran genus *Pediculus*; while the closely related genus *Pedicinus* occurs upon the lower Quadrumana.

Johnston (3) has compared the trematode fauna of the frogs of Europe, Asia, America, and Australia, and finds a common occurrence of species of *Pneumonœces* in the lungs, *Pleurogenes* in the intestine, *Diplodiscus* in the rectum, and *Gorgodera* in the bladder. He finds flukes from *Dasyurus* and *Ornithorhynchus* intermediate between the Fasciolinæ of higher mammals and the Psilostominæ of the Sauropsida. He also finds (4) that species of *Linstowia* (Cestoda) and *Harmostomum* (Trematoda) from Australian marsupials have their nearest relatives among species of the same genera from American marsupials. The parasitic Platodes, though not total obligate parasites in the same sense as the Mallophaga, show the same relation to their hosts.

I find that, in general, the Mallophaga parasitic on any avian order are recognisable at sight. In many cases, especially in certain genera, it is possible to state definitely that a parasite has come from a particular family of birds. Many species have a world-wide distribution, but always on closely related birds. Thus *Philopterus lari* occurs upon all gulls; *Lipeurus anatis* upon all ducks; *L. columbæ* upon all pigeons; *Colpocephalum flavescens* upon all hawks. The genus *Tetrophthalmus* has adopted a specialised habitat in the gular pouch of pelicans, and has its tracheal system specially modified in accordance with the changed conditions. Species of *Tetrophthalmus* occur on all pelicans, in the same situation, and are all similarly modified. The only reasonable explanation is that the parasites have had common origin.

Owing to equable conditions of nourishment and temperature, the Mallophaga have had no stimulus to evolve as rapidly as their hosts. This is abundantly proved by the fact that parasites from the various genera of a bird family are often hardly specifically distinct. The *Philopterus* of *Cuculus canorus* is with difficulty separable from those found upon the Australian genera *Cacomantis* and *Chalcococcyx*.

Bird phylogeny has always presented a difficult problem. The biological condition of the Mallophaga indicates that they can afford valuable evidence as

to bird relationships. I have already (6) brought forward strong circumstantial evidence to show that *Apteryx* is a Ralline bird, and not a Ratite.

Consequently, apart from its academic interest, the hypothesis may have a practical application.

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7. *The Morphology of the Telencephalon of* Spinax *as a Type of Elasmobranch Fore Brain.* *By* J. Stuart Thomson, *M.Sc., Ph.D.*

The following gray masses or functional areas have been recognised in the fore brain of *Spinax* : (*a*) *Area olfactoria medialis* in the rostral wall and in the median part of the anterior portions of the lateral lobes; (*b*) *Area olfactoria lateralis* in the lateral part of the more anterior portions of the lateral lobes; (*c*) *Hypostriatum* (Catois) or *Area superficialis basalis* (Johnston) occupying the greater part of the length of the telencephalon in a latero-ventral and medio-ventral position; (*d*) *Nucleus medialis septi* continuous ventrally with the last area mentioned, and occupying a position internal to the downwardly directed spurs of the lateral ventricles; (*e*) *Primordium hippocampi* on the dorsal surface; (*f*) precommissural or paraterminal body, a ventral extension of the *Primordium hippocampi*; (*g*) *Primordium pallii somatici*, a correlation area occupying a lateral position in the walls of the præthalamus or telencephalon medium; (*h*) *Nucleus præopticus*, an area disposed round the præoptic recess.

The following fibre-tracts have been located : (1) *Tractus olfactorius lateralis* and *Tractus olfactorius medialis*; (2) *Tractus olfacto-corticalis lateralis rectus*; (3) *Tractus olfacto-corticalis medio dorsalis*; (4) *Tractus olfacto-corticalis septi* or *Tractus cortico-medialis* of Botazzi and Kappers; (5) *Tractus olfacto-hypothalamicus*; (6) *Tractus pallii*; (7) *Tractus hippocampi*; (8) *Commissura pallii posterior*; (9) a tract which may be the fornix of authors, but which does not agree in the distribution of the fibres; (10) *Tractus tæniæ* (Edinger); (11) *Tractus thalamo-corticalis.*

The author has not obtained any satisfactory or conclusive evidence of the existence of a tract which might be correctly termed the *corpus callosum.*

The paper was illustrated by fifty drawings showing the gray masses and fibre-tracts noted in the preceding paragraphs.

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8. *The Metamorphosis of* Bilharzia, *with Demonstration of Specimens.* *By* Lieut.-Colonel R. T. Leiper, *R.A.M.C.*

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION:—MAJOR H. G. LYONS, D.Sc., F.R.S.

WEDNESDAY, SEPTEMBER 8.

The President's Address was read in his absence, as follows:—

The Importance of Geographical Research.

THIS year, when the British Association is holding its meeting in times of the utmost gravity, the changed conditions which have been brought about by this War must occupy the attention of all the Sections to a greater or less extent, and our attention is being called to many fields in which our activities have been less marked or more restricted than they might have been, and where more serious study is to be desired. The same introspection may be usefully exercised in geography, for although that branch of knowledge has undoubtedly advanced in a remarkable degree during the last few decades, we have certainly allowed some parts of the subject to receive inadequate attention as compared with others, and the necessity for more serious study of many of its problems is abundantly evident.

Nor is the present occasion ill adapted to such an examination of our position, for when the British Association last met in this city, now twenty-eight years ago, the President of this Section, General Sir Charles Warren, urged in his address the importance of a full recognition of geography in education on the grounds that a thorough knowledge of it is required in every branch of life, and is nowhere more important than in diplomacy, politics, and administration.

Matters have certainly advanced greatly since that time, and a much fuller appreciation of geography now exists than that which formerly prevailed. At the time of the address to which I have referred the serious study of geography in this country was on the eve of important developments. The Council of the Royal Geographical Society had for some time been urging the importance of geography being studied at the Universities so that there should be an opportunity for advanced students to qualify themselves as scientific geographers by study and original research in the subject. The time had arrived for this ideal to become an accomplished fact, and in the following year, 1888, a Reader in Geography was appointed at Oxford University, and a Lectureship in the same subject was established at Cambridge. Since then the advance has been steady and continuous not only in the increased attention given to the subject, but also in the way in which it is treated. The earlier bald and unattractive statistical presentation of the subject has now been almost everywhere replaced by a more intelligent treatment of it, in which the influences of the various environments upon the life which inhabits a region are appreciated, and the responses to such influences are followed up. Instruction in the subject is given by those who have seriously studied it, who realise its importance, and who are in a position to train up new scientific workers in the field of geography. Though much remains to be done there should be now a steady output of geographical investigators capable of providing an ever-increasing supply of

carefully observed data, which they will have classified methodically and discussed critically, in order that these may be utilised to form sound generalisations as to their relationships and sequence in accordance with the method which is employed in all scientific work.

In order that we may see what advance has been made in the scientific study of geography in this country during the last quarter of a century, we must turn to the results that have been attained by the activity of geographical investigators who have devoted themselves to the serious study of various phenomena, and the detailed investigation of particular regions. If we do so I think that we must admit that the number of original investigators in scientific geography who are extending its scope in this way is not so large as it might be, nor are we yet utilising sufficiently all the material which is available to us. Anyone who will examine the geographical material which has been published in any period which he may select for review will find that purely descriptive treatment still far outweighs the analytical treatment which alone can lead to definite advances in scientific geography. If pleasing descriptions of this or that locality are sought for, they are for the most part to be found readily in the very large amount of such material that has been and is being published each year by residents, travellers, and explorers; but if information is desired in the prosecution of a piece of geographical research, we are checked by the lack of precise details. Few of this class of descriptions are sufficiently definite to enable the necessary comparisons to be made between one locality and others which are similarly situated; thoroughly quantitative treatment is for the most part lacking, and while a pleasing picture is drawn which is probably true in character, it is usually inadequately furnished with those definite facts which the geographer requires.

I propose, therefore, to examine a little more closely the question of geographical investigation and research in order to see where we stand and in what direction it behoves us to put forth our energies to the end that a branch of knowledge which is of such importance shall rest upon that basis of detailed study and investigation which alone can supply the starting-point for further advance The intricate and complicated character of the subject, the extent of its purview, the numerous points at which it touches and imperceptibly passes into other well-defined branches of knowledge, render the study of geography very liable to degenerate into a purely descriptive treatment of the earth's surface and all that is to be found thereon, rather than to follow the narrow path of scientific progress in which the careful collection of data furnishes the material for systematic discussion and study in order that trustworthy generalisations may be reached.

The opportunity to undertake long journeys through distant lands comes to few of us, but this is not the only direction in which research can be profitably undertaken, for there is no part of these islands where a geographer cannot find within his reach some geographical problem which is well worth working out, and which, if well and thoroughly done, will be a valuable contribution to his science. Even for such as cannot undertake such field work the library will provide a host of subjects which have not received nearly the amount of attention and of careful study that they deserve. The one thing essential is that the study should be as thorough as possible, so that all the contributory lines of evidence shall be brought together and compared, and so that the result may prove to be a real addition to geographical science on which other workers may in their turn build.

For those who desire to undertake such investigations there is at any rate no lack of geographical material, for travellers, explorers, and others engaged in various occupations in every part of the world are continually recording their experiences and describing their surroundings in books and pamphlets · they recount their experiences to the Geographical Societies, who apparently have no difficulty in obtaining communications of wide interest for their meetings. Most portions of the British Empire as well as regions belonging to other nations are in these days more or less fully examined, surveyed, and investigated with a view to their development, and those who undertake such work have ample opportunities for the most part for preparing descriptions of the lands in which they have sojourned and with which they are well acquainted. But although the material is so ample the quality of it is not

generally such as makes it suitable for an adequate study of the phenomena or the region to which it relates. The ease with which a tract of country or a route can be described by the traveller, and the attractiveness of such a description of a little-known region, results in the provision of a vast quantity of geographical information, the greater part of which has probably been collected by those who have no adequate training in the subject. In such cases it is not uncommon for the writer to disclaim any geological or botanical knowledge, for instance, but the great majority of those to whom the opportunity is given to travel and see new lands and peoples are fully convinced of their competence to describe accurately and sufficiently the geography of the regions which they traverse. But anyone who has had occasion to make use of such material in a serious investigation is only too well aware how little precise and definite information he will be able to extract from the greater part of this wealth of material, and in most cases this is due to the traveller's lack of geographical knowledge. He probably does not know the phenomena which should be observed in the type of region which he is traversing, nor can he read the geographical evidence which lies patent to a trained observer at every point of the journey; much, therefore, of what he records may be of interest, but probably lacks data which are essential to the geographer if he is to understand the geographical character of the region, and utilise it properly.

Thus it happens that although the amount of geographical material which is being garnered may be large, the proportion of it which is available for use in a scientific investigation of an area is smaller than is probably realised by those who have not made the experiment. And yet it is only by this scientific investigation of selected localities or of a single phenomenon, and by working them out as thoroughly as possible, that any real advance in geographical science can be made. The accounts of such pieces of work will not appeal to those who desire picturesque descriptions of little-known lands, but they will be welcomed by geographers who can appreciate the value of such studies. There should now be an ever-increasing number of such geographers, trained to proceed in their investigations by the true scientific method, and there should be a very considerable amount of sound work in various branches of the subject which aims at thoroughly investigating some phenomenon, or group of phenomena, so as to present a grouping of data, carefully verified and critically discussed, in order to arrive at conclusions which may form a useful addition, however small, to the sum of our geographical knowledge.

So far as I am able to judge, the output of serious work of this character is not nearly as large as it should be, and I would indicate some fields in which there is a lack of individual work of this character. Until more of it is undertaken we shall lack in this country the material from which the foundations of scientific geography can be built up, and while our own islands and the various parts of the British Empire furnish unrivalled opportunities for such work, there are still far too many subjects where the most thorough investigations have been made in other countries.

Mathematical Geography presents a field for research which had comparatively little attention paid to it in this country. In many respects this part of the subject is peculiarly suitable for such treatment, since it admits of the employment of precise methods to an extent which is not always practicable in cases where so many of the factors can only be approximately defined. The determination of positions on the earth's surface is carried to great refinement in the national surveys of most civilised countries in order to furnish the necessary controls for the preparation of large-scale maps, but when we pass to the location of travellers' routes, where considerable allowance has to be made for the conditions under which the observations have to be taken, we find that very inadequate attention is usually paid to the discussion of the results. Usually a mean value for each latitude, longitude or azimuth is obtained by the computer, and he remains satisfied with this, so that when the route of another traveller follows the same line or crosses it at one or more points, it is almost impossible for the cartographer to say which of the two determinations of any position is entitled to the greater confidence. In this class of work, whether the results are obtained from absolute observations at certain points or from the direction of march, and the distance traversed, it is quite practicable to determine the range of uncertainty within which the

positions of different points are laid down, and it is eminently desirable that this should always be done in order that the adjustment of various routes which may intersect in partially-known regions may be adjusted in accordance with definite mathematical processes. Some important expeditions on which infinite labour and considerable sums have been expended have presented their results, in so far as they relate to the routes which have been followed and the position of points which have been determined, in such a way that it is impossible to say within what precision such positions have been determined, and consequently any combination of these results with those of later expeditions has to be carried out empirically, since adequate data are no longer available for the employment of better and more scientific methods.

This crude and unsatisfactory way of treating observations, which in many cases have been obtained under conditions of the greatest difficulty and even hardship, is largely due to the lack of interest which geographers have shown in this part of their subject. Methods of observation and methods of computation are rarely discussed before any of our Geographical Societies or in any of our publications, and it is only by such discussions that the importance of properly working out the available material at a time when the observer can be consulted on points which are doubtful, or where further explanation is desirable, becomes generally appreciated.

No set of physical or astronomical observations is ever discussed or even presented without the degree of precision or reliability being definitely stated; yet in geography this sound rule is too often neglected.

There are several regions where travellers' routes intersect which should provide ample material for the careful reduction and adjustment of the results I fear, however, that there would be great difficulty in obtaining the original observations which are indispensable in such an investigation, and in the interest of research it is highly desirable that the original documents of all work of importance should be preserved and the place where they may be consulted recorded in the published account.

There is room in the geographical investigation of sea and land, even within the limits of the British Empire, for the employment of methods of observation and computation of the highest precision as well as of the simpler and more approximate kinds, but everyone who presents the results of his work should deem it his first duty to state explicitly the methods which he employed, and the accuracy to which he attained, in such a form that all who make use of them can judge for themselves of the degree of their reliability.

In such work, while the instruments used are of great importance, too often the briefest description, such as 'a 4-inch theodolite,' is deemed sufficient. If the observer wishes his work to be treated seriously as a definite contribution to science we require to know more than this, and a clear account of the essentials of the instrument, a statement of its errors, and of the methods of observation adopted are the least that will suffice. The account of any expedition should treat so fully of the instruments, observations, and computations utilised to determine the positions of places visited that anyone can re-examine the evidence and form his opinion on the value of the results obtained. A mere tabular statement of accepted values, which frequently is all that is provided, is of small value from a scientific point of view. Probably one reason for this state of things is that too little attention is being paid by geographers to their instruments. Theodolites, levels, compasses, clinometers, tacheometers, plane-tables, pantographs, co-ordinatographs, planimeters, and the many other instruments which are used by the surveyor, the cartographer, the computer, have in no case arrived at a final state of perfection, but it is seldom that we find a critical description of an instrument in our journals. Descriptions there are from time to time, but these are for the most part weak and insufficient. Not only is a technical description required, which treats fully of both the optical and mechanical details, but we need an extended series of observations with the instrument which have been made under the ordinary conditions of practical work, and these must be mathematically analysed, and the degree of the reliability of the results clearly demonstrated. The description should be equally thorough and complete, including scale drawings showing the construction of the instrument as well as photographs of it. Nothing less than this is of any use to the scientific cartographer.

While I am on the subject of instruments I would draw attention to the importance of the whole history of the development of surveying instruments. In the latter part of the eighteenth century Great Britain provided the best class of surveying instruments to all countries of Europe, at a time when high-class geodetic work was being commenced in several countries; and about this time von Reichenbach spent a part of his time in this country working in the workshops of Dollond and learning this particular class of work. Upon his return to Bavaria he set up at Munich that establishment which soon provided instruments of the highest class for many of the cadastral surveys which were being undertaken in Central Europe. At Munich there is now a fine typical collection of such instruments, but in this country the early advances of British instrument-makers of surveying instruments are far from being adequately represented in our National Museum in a manner commensurate with their importance. The keen and enlightened zeal of geographers who are interested in this branch of the subject would doubtless quickly bring to light much still remaining that is of great interest, but which is yet unrecognised, while a closer attention to instrumental equipment would lead to improvements and advances in the types that are now employed. There is no modern work in this country on the development of such instruments, and references to their history are conspicuously rare in our journals, so that there is here an opportunity for those whose duties prevent them from undertaking travel or exploration of a more ambitious kind. In the same way, those whose opportunities of field work are few can find a promising field of study in the early methods and practice of surveying which have been discussed by many authors from classical times onwards, and for which a considerable amount of material exists

In Geodesy and Surveying of high precision there is ample scope for all who are attracted by the mathematical aspect of the subject; the critical discussion of the instruments and methods employed and results obtained, both in this country and in other lands, provides opportunity for much work of real value, while its bearing upon geology, seismology, &c., has not yet been adequately treated here. The detailed history of this part of our subject is to be found in papers which have been published in the technical and scientific journals of other countries for the most part; here too little attention has been given to the subject, in spite of the large amount of geodetic work which has been executed in the British Empire, and which remains to be done in our Colonies and overseas Dominions.

The final expression of the surveyor's detailed measurements is found in the map, and the adequate representation of any land surface on a map-sheet is both a science and an art. Here we require additional work on all sides, for there is hardly any branch of geography which offers so remunerative a field for activity as cartography. We need the co-operation of trained geographers to study requirements, and to make acquaintance with the limits of technical methods of reproduction, so that they may be in a position to deal with many questions which arise in the preparation of a map regarding the most suitable mode of presentation of data, a matter which is purely geographical, but which at the present time is too often left to the skilled draughtsman. Neither the compilation nor the reduction of maps are merely mechanical processes. The first requires great skill and care as well as technical knowledge and a sound method of treatment if the various pieces of work which are brought together to make up the map of any considerable area are to be utilised according to their true worth. This demands a competent knowledge of the work which has been previously done on the region, a first-hand acquaintance with the data collected by the earlier workers, and the critical examination of them in order that due weight may be given to the better material in the final result This is not a task to be handed over to the draughtsman, who will mechanically incorporate the material as though it were all of equal accuracy, or will adjust discrepancies arbitrarily and not on any definite plan. Such preliminary preparation of cartographical material is a scientific operation which should be carried out by scientific methods and should be completed before the work reaches the draughtsman, who will then have but to introduce detail into a network of controls which has been prepared for him and of which the accuracy at all points has been definitely ascertained. Similarly in the second case the

elimination of detail which must of necessity be omitted is an operation needing the greatest skill, a full understanding of the material available, and an adequate appreciation of the result which is being aimed at, such as is only to be found in a competent geographer who has made himself intimately acquainted with all the material which is available and has his critical faculty fully developed.

The use of maps has steadily increased of recent years, but we should look forward to an even more widely extended use of them in the future; and this will be greatly facilitated if there are geographers who have made themselves masters of the technique of map reproduction and, as scientific geographers, are prepared to select such data as are needed for any particular class of map on a well-considered method, and not by the haphazard procedure to which the want of a scientific study of cartographic methods must inevitably lead. The paucity of papers dealing with practical cartography and the compilation of maps is clear proof that this branch of the subject awaits far more serious attention than it now receives.

All these problems are well within the reach of the geographer to whom the opportunity of travel in other regions does not come, and in them he will find ready to his hand a field of research which is well worth working and which will amply repay any labour that is spent upon it. The same precise methods of investigation which are employed in the discussion of observations should be applied to all cartographic material in order to ascertain the exact standard of its reliability, in which is included not only the correctness of distance and direction, but also the accuracy of the information which has been incorporated in it; and these may be brought to bear also on those early maps of which so many are preserved in our libraries in this country. In this field of study several investigators have already achieved results of great interest and value, but I think that they will be ready to admit that there is here a wide and profitable field of activity for many more workers who will study closely these early maps and, not being contented with verbal descriptions, will use quantitative methods wherever these are possible.

In the study of map projections some activity has been visible in recent years, and we may hope that those who have worked in this branch of the subject will see that British Geography is provided with a comprehensive manual of this subject which will be worthy of the vast importance of cartography to the Empire. The selection of suitable projections is receiving much more attention than was formerly accorded to it, but the number of communications on this subject which reach geographical journals are few and far between. The subject is not one which can appeal strongly to the amateur geographer, but its importance renders it imperative that the scientific geographer who realises its intimate bearing upon all his work should so arrange that the matter does not fall into the background on this account.

A closer relation and a more active co-operation between those who are prepared to work seriously at cartography and its various problems may reasonably be expected to raise the standard of that class of map which is used to illustrate books of travel, or works descriptive of a region. At the present time the inadequate character of many of the maps and plans which are reproduced in such publications shows clearly that the public demand for maps which have been compiled with a view to illustrating the volume in question is still very ineffective.

The whole subject of cartography, with its component parts of map projection, compilation, reproduction, cartometry and the history of its development, is so important, not only to the individual geographer but also to the advancement of scientific geography, that we should aim at fostering it and encouraging the study of it in every way, and it will be the zeal of individuals rather than the benevolent aid of institutions which will achieve this.

But it may be suggested that the lack of activity in Mathematical Geography is due to the somewhat specialised nature of the subject, and to the fact that the number of those who have received an adequate mathematical training and are prepared to devote themselves to geography is few. When we turn to Physical Geography in its treatment of the land we do find a field which has been more actively worked, for this is just the one to which the traveller's and

explorer's observations should contribute most largely, and where therefore their material should be utilised with the best results. Even here there is room for much more work of the detailed and critical type, which is not merely general and descriptive, but starts from the careful collection of data, proceeds to the critical discussion of them, and continues by a comparison of the results with those obtained in similar observations in other regions.

To take a single branch of Physical Geography, the study of Rivers, the amount of accurate material which has been adequately discussed is small. In our own country the rainfall of various river basins is well known through the efforts of a meteorological Association, but the proportion of it which is removed by evaporation, and of that which passes into the soil, has only been very partially studied. Passing to the run-off, which is more easy to determine satisfactorily, the carefully measured discharges of streams and rivers are not nearly so numerous as they should be if the hydrography of the rivers is to be adequately discussed; for although the more important rivers have been gauged by the authorities responsible for them in many cases, the results have usually been filed, and the information which has been published is usually a final value but without either the original data from which it has been deduced, or a full account given of the methods of measurement which have been employed. For the requirements of the authority concerned such a record is no doubt adequate, but the geographer requires the more detailed information if he is to co-ordinate satisfactorily the volume discharged with local rainfall, with changes in the rates of erosion or deposition, and the many other phenomena which make up the life-history of a river. Here too it is usually only the main stream which has been investigated; the tributaries still await a similar and even fuller study. A valuable contribution to work of this kind exists in the hydrographical study of the Medway and of the Exe which has been undertaken by a Committee of the Royal Geographical Society during recent years, and this may serve as a guide to other workers; but, however welcome such a piece of work may be, I should much prefer to see the hydrography of a tributary of a river system worked out by a geographer as a piece of individual work, just as the geology or the botany or the zoology of a single restricted area is investigated by those whose interests are centred in these subjects.

In the same way we still know too little of the amounts of the dissolved and suspended matter which is carried down by our streams at various seasons of the year and in the different parts of their course. This class of investigation does not need very elaborate equipment, and may provide the opportunity for much useful study, which may be extended as information is increasingly acquired. In this way when numerous individual workers have studied the conditions prevailing in their own areas, and traced them through their seasonal and yearly variations, we shall possess a mass of valuable data with which we may undertake a revision of the results which have been arrived at in past years by various workers from such data as were then at their disposal.

In this one branch of the subject there is ample scope for workers of all interests in the measurement of discharges, in the determination of level, and of the movement of flood waves, in determining the amount of matter transported both in suspension and in solution, in tracing out the changes of the river channel, in following out the variation of the water-table which feeds the stream, in ascertaining the loss of water by seepage in various parts of its course, and generally in studying the hundred other phenomena which are well worth investigating, and which give ample scope for workers of all kinds and of all opportunities. There is work not only in the field, but also in the laboratory and in the library which needs doing, for the full account of even a single stream can only be prepared when data of all classes have been collected and discussed.

On the Scottish lakes much valuable scientific work has been done, and also on some of the English lakes, so that excellent examples of how such work should be done are available as a guide to anyone who will devote his spare time for a year or two in making a thorough acquaintance with the characteristics and phenomena of any lake to which he has access.

Coast-lines provide another class of geographical control which repays detailed study, and presents numberless opportunities for systematic investiga-

tion and material for many profitable studies in geography. The shores of these islands include almost every variety of type, and furnish exceptional opportunities for research of a profitable character, especially as lying on the border-line between the domain of the oceanographer on the one hand and the physiographer on the other. The precise methods of representation which are possible on the land have to give way to a more generalised treatment over the sea, and the shore line is liable to be handed over to the latter sphere, so that there is much interesting and useful work open to anyone who will make an accurate and detailed study of a selected piece of coast-line, co-ordinating it with the phenomena of the land and sea respectively.

The teaching of Professor Davis in pressing for the employment of systematic methods in describing the landscapes with which the geographer has to deal has brought about a more rational treatment, in which due recognition is given to the structure of the area, and the processes which have moulded it, so that land forms are now for the most part described more or less adequately in terms which are familiar to all geographers and which convey definite associated ideas, in the light of which the particular description is adequately appreciated. It has been urged by some that such technical terms are unnecessary and serve to render the writings in which they occur intelligible only to the few; that anyone should be able to express his meaning in words and sentences which will convey his meaning to all. There is no great difficulty in doing this, but in such descriptions to convey all that a technically-worded account can give to those who understand its terms would be long and involved on account of the numerous related facts which would be included. It is consequently essential in all accurate work that certain terms should have very definite and restricted meanings, and such technical terms, when suitably chosen, are not only convenient in that they avoid circumlocution, but when used in the accepted sense at once suggest to the mind a whole series of related and dependent conditions which are always associated with it.

The compilation of a glossary of geographical terms has been in progress in this country for many years without having reached finality, and much of the difficulty which has been experienced is doubtless due to the fact that so many words have not been consistently used with a well-defined meaning. Such looseness of expression is more liable to occur in the case of foreign words which have been imported in the first case by writers who are not scientifically trained, and therefore do not use them in connection with a specified set of conditions. This, however, is unimportant if only scientific geographers, when they accept a term as a desirable addition to the geographical vocabulary, will associate it definitely with such conditions and use it consistently in that connection. As an instance I may quote the word "sadd," which etymologically means to block, or stop. This term was naturally and reasonably used to indicate masses of uprooted marsh vegetation which had been carried along by the current and, if checked at a sharp bend or a narrow point of the stream, blocked the channel. So long as it is used in this restricted sense it is a useful term to describe a phenomenon which occurs under certain definite conditions and which leads to equally well-defined geographical results. This use of it is associated with a meandering river channel in an alluvial flood plain, where shallow lagoons occur, in which such marsh vegetation grows luxuriantly; when this vegetation is uprooted by storms and carried by the rising water into the main stream it provides the drift material which makes up the block or 'sadd.'

But this term has been extended immoderately to mean the region in which these physical conditions occur, or the type of vegetation which grows under these conditions, and even the type of country where such conditions prevail. One writer has even used the word in describing fossil vegetation of a character such as is associated with marsh lands.

The crystallisation of such geographical terms into true technical terms is an important step in the furtherance of scientific geography, but it must be done by the geographers themselves, and no means of doing this is more fruitful than the work of original research and investigation in definite areas or on specific problems.

It would take too long to discuss each branch of physical geography and indicate the opportunities for individual effort, but what has been said of one

may be said of all the others. Not only in all parts of the Empire but in these islands also there is ample opportunity for the detailed geographical study of single localities or individual phenomena, just as much as in geology, in botany, or in zoology; and it is these separate pieces of work which, when thoroughly carried out and critically discussed, provide the material on which wider generalisations or larger investigations can be based. Herein lies, therefore, the importance of the prosecution of them by as many workers as possible, and the value of communicating the results to others for criticism and for comparison with the results which they have obtained; for such work, if it cannot be made accessible to other workers in the same and related fields, loses a large proportion of its value.

If we now consider some of the problems of human geography we shall find the need for such systematic study to be even greater; for the variable factors involved are more numerous than in physical geography, and many of them are difficult to reduce to precise statement; the quantitative study of the subject is therefore much more difficult than the qualitative or descriptive, so that the latter is too frequently adopted to the exclusion of the former. The remedy lies, I believe, in individual research into special cases and special areas where the factors involved are not too numerous, where some of them at least can be defined with some accuracy, and where, consequently, deductions can be drawn with some precision and with an accuracy which gives grounds for confidence in the result. The settlements of man, his occupations, his movements in their geographical relations are manifested everywhere, and subjects of study are to be found without difficulty, but their investigation must be based on actual observation, and on data which have been carefully collected and critically examined, so that the subject may be treated as completely as possible, and in such a way that the evidence is laid before the reader in order that he may form his own conclusions.

It is probable that some of the lack of precision which is to be found in this part of the subject is to be attributed to the want of precision in its terminology. For many things in human geography good technical terms are required, but these must be selected by those who have studied the type or phenomenon concerned and have a clear idea of the particular conditions which they desire to associate with the term; this is not the work of a Committee of Selection, but must grow out of the needs of the individual workers.

There is, it must be admitted, no small difficulty in using the same preciseness of method in this portion of the subject as is readily attainable in mathematical geography, and is usually practicable in physiography; but at any rate it is undesirable to indicate any condition as the controlling one until all other possible influences have been carefully examined and have been shown to have less weight than that one which has been selected.

Whether the investigation deals with the settlements of man or his movements and means of communication it is important that in the first instance problems of a manageable size should be undertaken and thoroughly treated, leaving larger areas and wider generalisations until a sufficient stock of thoroughly reliable material which is in the form in which it can properly be used for wider aims is available.

The relation of geographical conditions to small settlements can be satisfactorily worked out if sufficient trouble is taken and all possible sources of information, both of present date and of periods which have passed away, are utilised. Such studies are of a real value and pave the way to more elaborate studies, but we need more serious study of these simpler cases both to set our facts in order and to provide a methodical classification of the conditions which prevail in this part of the subject. Out of such studies there will grow such a series of terms with well-defined associations as will give a real precision to the subject which it seems at the present time to lack.

The same benefit is to be anticipated from detailed work in relation to man's communications and the interchange of commodities in all their varied relations. Generalised and descriptive accounts are readily to be found, and these are for the most part supported by tables of statistics, all of which have their value and present truths of great importance in geography, but the spirit of active research which aims at clearing up thoroughly a small portion of the wide field

of geographical activities has unequalled opportunities in the somewhat shadowy relations between the phenomena which we meet in this part of the subject, for focussing the facts better, and obtaining a more exact view of the questions involved.

Where the geography of States (political geography) is concerned the same need for original investigation as a basis for generalisations may be seen. At the present time there is much said about the various boundaries of States, and in general terms the advantages and disadvantages of different boundaries under varied conditions can be stated with fair approximation to accuracy. But I do not know of many detailed examinations of these boundaries or portions of them where full information of all the factors involved can be found set out in an orderly and authoritative manner, thus forming a sure foundation for the generalised description and providing the means of verifying its correctness or revising it where necessary.

Perhaps there is really more scientific research in geography being undertaken by individuals than I have given credit for, but certainly in geographical periodicals, and in the bibliographies which are published annually, the amount shown is not large; neither is the number of authors as large as might be expected from the importance and interest of the subject and from the activity of those centres where geography is seriously taught. There seems to be no reason why individual research on true scientific lines should not be as active in geography as it is in geology, botany, zoology, or any other branch of knowledge; and, just as in these, the real advance in the subject is dependent on such investigations rather than on travels and explorations in little-known lands, unless these too are carried out scientifically and by thoroughly trained observers who know the problems which there await solution, and can read the evidence which lies before them on their route.

If research in these directions is being actively prosecuted, but the appearance of its results is delayed, let us seek out the retarding causes if there be any, and increase any facilities that may be desirable to assist individual efforts.

Short technical papers of a thoroughly scientific character, such as are the outcome of serious individual research, are, of course, not suitable for those meetings of Geographical Societies where the majority of the Fellows present are not scientific geographers, but should be presented to small meetings of other workers in the same or allied fields, where they can be completely criticised. The reading, discussion, and the publication of papers of this class are for geography a great desideratum, for it is in them and by them that all real advance in the subject is made, rather than by tales of travel, however interesting, if these are not the work of one trained in the subject, having a knowledge of what he should observe, and of what his predecessors have done in the same field. The regional aspect of geography in the hands of its best exponents has given to young geographers a wide and comprehensive outlook on the interaction of the various geographical factors in a region, the responses between the earth's surface and the life upon it, and the control that one factor may exercise upon another. In this form the fascination of geographical study is apparent to everyone, but I sometimes wonder whether the exposition of such a regional study by one who is thoroughly master of the component factors, having a first-hand knowledge of all the material involved, and knowing exactly the reliability of each portion, impresses sufficiently upon the student the necessity of personal research into the details of some problem or phenomenon in such a way as to gain a real working acquaintance with them; or does it on the other hand tend to encourage generalisations based on descriptive accounts which have not been verified, and where coincidences and similarities may be accepted without further inquiry as evidence of a causal connection which may not really exist? I imagine that the student may be attracted by the apparent simplicity of a masterly account of the geographical controls and responses involved, and may fail to realise that geographical descriptions, even though technically phrased, are not the equivalent of original quantitative investigation, either for his own education or as a contribution to the subject.

For these reasons I believe that Societies can do far more good in the promotion of geography as a science by assisting competent investigators, by the loan of books and instruments, and by giving facilities for the discussion

and publication of technical papers, than by undertaking the investigation of problems themselves.

Among the earlier Presidential Addresses of this Section some have laid stress on the importance of the recognition by the State of geography in education; others have represented the great part which the Geographical Societies have played in supporting and advancing the subject; others again have urged the fuller recognition of geography by Educational Institutions. I would on this occasion attach especial importance to the prosecution of serious research by individuals in any branch of the subject that is accessible to them, to the discussion of the results of such work by others of like interests, and to the publication of such studies as having a real value in promoting the advancement of scientific geography.

Before the President's Address the following Papers were read :–

1. *The Map on the Scale of* 1 :1,000,000. *By* A. R. HINKS, *F.R.S.*

2. *The Representation of the Distribution of the Population on Maps.* *By* B. C. WALLIS.

The purpose of this short paper is to introduce different methods of representing upon maps facts concerning population, and to elicit opinions and criticisms upon these methods in order to arrive at some conclusions which may be useful in connection with the million map.

It has been suggested that the million map might be used to show (i) the density of the population and (ii) the distribution proportionally of the various peoples of Europe. For the purpose of illustration the Hungarian portion of the Buda-Pest sheet of the million map has been chosen as it probably presents the greatest difficulties in this connection. The facts which are demonstrated are based upon the Hungarian Census for 1910 and upon three administrative divisions of the country : (*a*) the counties, (*b*) towns with an organised council, and (*c*) municipal towns. These legal divisions are not to be depended upon in connection with the population as is shown upon the maps.

Maps A and B show density of population.

Maps C and D show the distribution of the peoples

Map A indicates density of population by the usual methods.

Map B is due to a suggestion from Mr. A. R. Hinks; the principles of contour lines are applied to population. It is imagined that in each administrative area the population is evenly distributed and that the density value when located at the centre of the division can be treated in the same fashion as a spot height in contouring. The net result is that the gradation of density is suggested in a continuous fashion and that abrupt changes and sharp angles in the boundary lines tend to disappear.

It is desired that an opinion be expressed upon the relative merits of Map B compared with Map A.

Map C takes each nationality and shows its distribution as a percentage of the total population by the method of Map B. It is not easy to show more than three nationalities in any area, and this map does not indicate the presence of small minorities.

Map D shows the complete facts numerically and is less pictorial though more detailed than Map C.

It is desired that an opinion be expressed : firstly, upon Map C in comparison with the usual maps of this type; and, secondly, upon Map D in comparison with Map C

After the President's Address (see p. 478) the following Papers were read :—

3. *Geographical Considerations arising out of the Visit to Australia in 1914: a Comparison of Vegetation Maps.* By O. J. R. HOWARTH, *M.A.*

We have accustomed ourselves to think of the continent of Australia in terms of maps on very small scales. The use of such maps is justified, in part, by the fact that, speaking broadly, Australia is a continent singularly simple in outline and form. But the employment of small scales makes it the more important, on the one hand, that precision, where precision is possible, should be adhered to, and, on the other hand, that where precise data do not exist, precision should not be assumed.

Three maps are shown : on all of them the same colouring is used to show different types of natural vegetation, yet the appearance of each differs widely from the others. The maps, chosen practically at hazard, are labelled A, B, and C, and are enlarged from small maps to be found respectively in a standard authoritative work on plant geography, a well-known school-book, and a well-known atlas. In copying the representations of the various types of vegetation were standardised. Some of the main differences between the maps are here summarised :

(1) *Monsoon Forest of the North.*—Map A shows a continuous belt of it eastward from York Sound; B a continuous belt only east of the Victoria River; C shows the northern forest in isolated patches. A shows Cape York peninsula as wholly forested, B nearly so, C along the east coast only.

(2) *Forests of the Eastern and South-Eastern Highlands.*—A and B show a forest belt right along the eastern seaward slope; C interrupts this belt in the vicinity of Townsville (Queensland), bringing the grassland of the interior down to the coast. In New South Wales A gives the temperate forest and woodland an extreme width of 200 miles; C gives it fully 400; B gives an intermediate width. A, distinguishing 'parklands, woods, and meadows' from 'forest,' allows the State of Victoria no true forest area large enough to be shown. B divides the south-eastern forest climatically (summer and winter rain forests) approximately along the political frontier between New South Wales and Victoria; C shows a division west of Melbourne—this distinction, however, is made merely between 'broad-leaved forest' and 'evergreen trees.'

B shows the scrub area, interrupting the forest in the lee of the Flinders Range (Victoria, South Australia), which A and C ignore. A remarkable divergence of opinion is seen respecting the forested area in the south-west of Western Australia.

Opinions may naturally vary as to what exactly constitutes forest, woodland, parkland, steppe, grassland, scrub or semi-desert, and desert. But, as regards *grassland*, C allows a much smaller total area in Australia than A or B. B recognises a strip of steppe bordering the Australian Bight, which A and C ignore, though it is insisted upon in various official and other publications, especially in connection with the trans-continental railway now building. B and C distinguish *desert* from *semi-desert* or *scrub*, but their distinctions are at variance, C showing a rather elaborate outline of the true desert areas, which would suggest that complete data existed for laying them down. A (perhaps wisely from the general educational standpoint) applies the term 'desert' more widely, to cover all these conditions.

It is in the north of Western Australia that the three maps are perhaps most completely at variance.

Making every allowance for divergence of opinion as to the connotation of terms and for erratic draughtsmanship, it would seem that the vegetation divisions of Australia have been allowed to get rather out of hand. Probably the same is true of vegetation maps of this sort, and of other distribution maps, for other parts of the world. Though the present may not be the time to undertake such work, it is suggested that the scrutiny and criticism of existing material (whether original maps or verbal description) for the compilation of certain classes of distribution maps might be entrusted to a small committee

of workers who would take up each his own topographical division after agreement on a general plan. Work might well begin upon data for vegetation maps (which ought to be of substantial value not only in the botanical but also in the economic geographical connection), and upon Australia.

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4. *The Relations of the Central Lakes of Westralia.* *By* Professor J. W. Gregory, *F.R.S.*

The dry lake basins of Western Australia have been represented as hollows due to deflation by wind, to corrosion by ice, or to the action of a former sea. The author has described them as basins left by the dismemberment of a Miocene river system, and in 1914 published a sketch map illustrating the course of the rivers so far as could be inferred from the levels then available. The issue of the southern sheet of a valuable 'Contour Map of Western Australia' by the Lands Department of that State throws much further light on the relief of the central plateau. According to that map the basins of the group of lakes, including Lakes Raeside, Ballard, Barlee, and Giles, are connected by land below the level of 1,250 feet, and the only outlet from that many-branched depression was south-west through Lake Deborah to the Swan River. According to the author's sketch-map the drainage from Lakes Giles, Barlee, and Ballard passed through Lake Raeside south-eastward to the sea, which once, probably in the Miocene Period, extended from the Great Australian Bight northward over the Nullabor Plains. The accurately determined railway levels from Kalgoorlie to Laverton indicate that the drainage from the Lake Ballard and Lake Raeside group was originally to the south-east. If the existence of the outlet from Lake Ballard through Lake Deborah be confirmed, this channel was probably of later date, and formed owing to the blockage of the south-eastern outlet through wind-borne drifts.

The Lands Department Contour Map indicates that the drainage from the country around Lake Way and Lake Wells, instead of passing south-eastward to the Nullabor Plains, flowed by a very circuitous route to the north and east of the Mount Margaret Goldfield instead of by the shorter route through the numerous lake basins between Lake Way and the former south-eastern sea.

The new 'Contour Map' and contributions to the physiography of Westralia by Messrs. Gibson and Jutson are in favour of the origin of these dry lakes as remnants of an extinct river system.

5. *The Burrinjuck Dam and the Murrumbidgee Irrigation Area.* *By* J. McFarlane [1]

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6. *The Discovery of Australia.* *By* H. Yule Oldham.

THURSDAY, SEPTEMBER 9.

The following Papers were read :—

1. *Joint Discussion with Section C on the Classification of Land Forms.* *Opened by* J. D. Falconer.

The investigation of processes is the common ground of Geology and Geography. The geographical processes, however, are less numerous than the geological, and are studied by geologists and geographers with a different purpose. The geologist studies these processes in order to elucidate the past history of the earth, the geographer in order to systematise the present topographical features of the surface. Geological interest in the geographical

[1] To be published in *Scott. Geog. Mag.*

processes thus ceases as soon as the so-called land forms have been referred to their respective processes or combinations of processes. Since most text-books of physical geography have been written from the geological point of view, it follows naturally that the treatment of land forms in these text-books is entirely subsidiary to the discussion of processes and offers no clue to the scientific definition and classification of individual forms. It is believed, however, that these submit themselves to systematic classification with almost as much ease as the subject-matter of other natural sciences, and that it falls clearly within the scope of geography as the science of the earth's surface to establish such a classification. The first attempt in this direction was made by Professor Passarge, of Hamburg, in 1912.[1] The classification outlined below is based upon similar principles and has already appeared in the *Scottish Geographical Magazine.*[2]

It is proposed to set up two classes of land forms, each containing two orders :

Class A. Endogenetic Forms.
Order I. Negative Forms.
Order II. Positive Forms
Class B. Exogenetic Forms
Order I Degradation Forms
Order II. Aggradation Forms.

The two orders of endogenetic forms are then subdivided into four families :

Family 1. Forms due to superficial volcanic activity.
2 Forms due to sub-crustal volcanic activity.
3 Forms due to radial movements.
4. Forms due to tangential movements.

Similarly the two orders of exogenetic forms are each subdivided into nine families :

Family 1. Forms due to the action of the run-off.
2. Forms due to the action of percolating water.
3. Forms due to the action of streams and rivers.
4 Forms due to the action of life.
5. Forms due to the action of lightning.
6 Forms due to the action of sun-heat.
7. Forms due to the action of the atmosphere.
8. Forms due to the action of frozen water.
9. Forms due to the action of the sea.

Each family is then subdivided into genera and species or specific forms. It is suggested that a land form be defined as any surface or slope which may be referred in origin to the operation of a single process or force. Monodynamic surfaces of this kind being rare, however, the commoner polydynamic surfaces may be classified according to the predominant force amongst those responsible for the production of the surface. This definition may be extended to include such surface features as cones or domes enclosed by one continuous surface, or such features as ridges or mounts enclosed by surfaces meeting in edges, provided that all these surfaces may be classified as examples of the same specific form.

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2. *Joint Discussion with Section H on Racial Distribution in the Balkans.*—See p. 672.

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3. *North China and Korea.* *By* P. M. Roxby, *M.A.*

This paper consisted of—

(1) A description of various aspects of Chinese and Korean life, illustrated by lantern slides.

[1] *Mitt. der Geog. Gesell. in Hamburg*, xxvi., 1912, p. 133.
[2] *S.G.M.*, xxxi., 1915, p. 57.

(2) A discussion of geographical factors affecting the economic and political development of North China, Manchuria, and Korea, with special reference to :

(*a*) The railway situation.
(*b*) The relations of China to Russia and Japan.
(*c*) China's interest in the European war.
(*d*) The work of the Japanese in Korea.

4. *Spitsbergen before the War.* *By* R. N. Rudmose Brown, *D.Sc.*

Last summer Dr. W. S. Bruce led an expedition to Spitsbergen which was supported by a grant from the British Association. Owing to abnormal ice conditions the projected work on the east—in Wybe Jansz Water—could not be carried out, while difficulties arising out of the war curtailed the work on the west. Dr. Bruce's absence in the Seychelles has prevented his presence at this meeting to give an account of his voyage, but the present paper embodies some of his work. Spitsbergen remains a No Man's Land despite the many acquisitions of land by subjects of more than one nation. Insecurity of tenure and considerable lawlessness are the result of this lack of control, and the economic development of the country is hindered. Among the minerals which occur in Spitsbergen are large quantities of coal, magnetite, and gypsum. Valuable marble is also found. Almost all the mineral-bearing territories on the west have been claimed by different companies, chiefly British; the east is less accessible, but several British claims occur there also. Altogether British subjects claim about 7,000 square miles of territory, on which several mines and quarries have been opened. Americans have the most valuable coal-mines, exporting annually large quantities to the north of Norway. It is tertiary coal, but of excellent steam quality. Russian enterprise in Spitsbergen ceased over fifty years ago when Russian trappers stopped frequenting the land. Lately there have been some small attempts on the part of Russians to acquire mining claims. Swedish activity has always been chiefly centred in exploration, particularly of a geological nature. Norway has a few unimportant mining claims, and a few years ago erected a powerful wireless installation. German claims were never of importance.

Hunting fur-bearing animals is a dying activity, due to the approaching extermination of the game by ruthless hunters. On the west game is now very scarce.

The proximity of Spitsbergen to the British Isles and the mainland of Europe is generally overlooked owing to the use of Mercator maps. From Norway it is only 400 miles, and it is within fifty hours' steaming by a fast cruiser from our shores. The west coast is remarkably free from ice, even in midwinter, and the winter climate does not preclude the continuance of mining throughout the year. In winter a number of miners are at work on British and American mines.

FRIDAY, SEPTEMBER 10.

The following Report and Papers were read :—

1. *Report on Atlas, Textual and Wall Maps for School and University Use.*—See Reports, p. 150.

2. *The Distribution of Population in the District around Leek.* *By* Raymond Curtis.

Leek is situated at the southern extremity of the Pennine uplands in an agricultural region with some industrial development.

The type of agriculture (depending upon the relief and soil) and the industrial development, past and present, largely explain the relative density of population in different parts of the area.

In the agricultural development of the district it is possible to distinguish

various stages in the evolution of a market town. A village nucleus of farm-houses arose at various places throughout the area wherever considerations of defence, ease of communications, water-supply, &c., led to a grouping together of habitations. The subsequent growth and development of this village nucleus depended mainly upon two factors—the area and the productivity of the region of which it was the focus. The stages of growth may be conveniently classified as the 'inn-village' (*e.g.*, Gradbach, Heaton, Bottomhouse), the 'shop-village' (*e.g.*, Meerbrook, Horton, Grindon), the 'fair-village' (*e.g.*, Hartington, Flash), and last, the market-town (*e.g.*, Leek, Cheadle, Longnor). For various reasons, but mainly through the development of communications, Leek now dominates the whole area.

The main industries of the region which have affected the density of population are coal-mining, cotton, silk, and copper manufactures, and silk-dyeing.

3. *The Middle Tees and its Tributaries: A Study in River Development*

By C. B. Fawcett, *B.Litt.*

The streams here considered are the middle portion of the Tees and its tributaries from Stainmore to the eastern edge of the Carboniferous rocks of the Pennines. The district which they drain is characterised by the presence of three distinct types of topography, viz. :

(1) A wide and comparatively smooth upland surface, sloping gently eastward, but cut off abruptly to the west by the Pennine Scar, with a few hills rising above it.
(2) A series of wide, shallow, mature valleys.
(3) A series of narrow and youthful valleys, which are for the most part sunk below the floors of the mature valleys.

The rocks of the district are almost entirely of Carboniferous age, mainly Lower Carboniferous limestones and shales in the southern half and Upper Carboniferous sandstones and shales in the northern. The complex topography is not primarily due to the rock structure, which is quite simple; but must be ascribed mainly to the work of the streams, influenced in some cases by lines of faulting.

Of these streams the middle part of the Tees is the longest and much the largest. It enters Middle Teesdale from the Upper Dale by the Eggleston Gap, with a sharp change in its general direction on doing so. It then flows for about six miles in an almost straight trench at the foot of the fault-line scarp of Marwood Scar, receiving several tributaries from the west and none from the east. At Barnard Castle the Tees bends eastward, and thence flows, along an arc convex to the south, to its junction with the Langley Beck through a series of alternating gorges and wider terraced valleys. On joining the Langley Beck the river resumes its E.S.E. direction, and two or three miles lower it leaves the Carboniferous rocks.

The largest of the tributary streams is the Greta. This rises in Stainmore Pass and flows eastward in a well-marked trough valley, in which part of its course is underground. East of Bowes it also flows in an arc convex to the south, but the general direction of its upper course is continued by a small stream, the Tutta Beck, which it intercepts near Greta Bridge. The Greta finally joins the Tees through a very narrow and steep gorge. About its lower course at least three changes in the drainage lines are traceable. The original consequent valley was continued directly eastward to the lowland; it is now occupied by three distinct streams, the R. Greta and the Tutta and Clow Becks. First the Greta was captured by a tributary of the Swale and diverted S.E. to that river. In its later diversion to an arc south of the direct valley line the Greta resembles several other streams in the neighbourhood. Lastly, at a very recent period it was captured by a small tributary of the Tees.

The second of these streams is the Balder, parallel to the upper Greta. This has lost its headwaters to the Eden system at a fairly recent period, and the capture has left at Balderhead a low pass through the Pennine crest. Its tributaries show clear examples of the development of a complex river system by successive captures of originally distinct and parallel consequent streams.

Of the lowland streams the chief is the Langley Beck. This flows in a wide

dale which continues the general direction of the Upper Tees and is approximately the chord of the great southward bend of the middle Tees. In the Staindrop Plains, an area of marsh finally reclaimed only a century ago, the beck is diverted southward to the Tees through a valley which is much narrower and younger than Langleydale. The main valley is continued eastward and occupied in turn by the Langton and Cocker Becks before it is merged in the lowland. This northern west-to-east valley is very similar to the one south of the Tees which is occupied by the River Greta and the Tutta and Clow Becks. These valleys contain many examples of the early effects of human interference with stream development.

There are thus in Middle Teesdale two principal west-to-east valley lines. The development of these valleys, the subsequent union of their waters in the Tees, which flows between them in a much younger valley, and the absorption of the smaller streams into this river system explain the great width of Teesdale in comparison with the neighbouring dales and the chief peculiarities of its streams. The direction of the consequent streams is a few degrees north of east, with a tendency to convergence from north and south due to the greater elevation of the Cross Fell and Ingleborough domes. The Tees crosses the consequent valleys, along a line determined mainly by fault-lines in the strata, and has thus become the master stream.

Except for the parts of streams in fault-line valleys and in subsequent reaches due to stream capture, there are few subsequent, and still fewer obsequent, streams; hence the river system as a whole is in a comparatively early stage of development. It is, however, the product of at least three distinct cycles of erosion :

1st. The comparatively smooth surface of the upland is part of a peneplain If its valleys were filled up it would be a plain sloping gently eastward, with its surface cutting across the rock strata at a small angle. The formation of this peneplain probably occurred during the Tertiary era

2nd. The wide shallow mature valleys mark the second cycle Their shallowness indicates that the change of base level which caused their formation was small; and their relation to the glacial drift and the route of the ice indicates that they had reached their full development before the Ice Age. The elevation which led to their formation probably occurred in the latter part of Tertiary time. The main consequent valleys are all of this type; and the more important of the subsequent valleys are also pre-glacial, though somewhat younger. The Ice Age does not seem to have caused any serious changes in the stream lines of Teesdale; but the extensive river terraces of many of the valleys probably date from the period following the melting of the ice.

3rd The deep and narrow gorges in which many of the streams flow are the product of the last cycle of development, which is still in a very youthful stage. Its initiation was due to a post-glacial uplift of the region.

The change from the second to the third cycle is readily seen in the longitudinal sections of the streams, most of which show very marked changes of slope. The fall is usually much greater in the lower course than in the middle A typical tributary valley consists of three clearly marked sections. First, the upper course on the upland with a very slight valley Second, a broad and shallow valley on the floor of which the stream meanders Third, a gorge in the bottom of this wide valley in which the stream rushes along over a series of rapids. These three sections of the valley repeat the three types of topography which characterise the district as a whole, and are the results of the three cycles of erosion to which its present form is due.

4. *Some Considerations on Former Movements and Distribution of Population in South Britain, and its Influences.* By Professor H. J. Fleure.

5. *The Study of Cities*
By Professor Patrick Geddes *and* Miss M Barker.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.*

PRESIDENT OF THE SECTION:—Professor W. R. SCOTT, M.A., D.PHIL., LITT.D., F.B.A.

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address:—

Economics of Peace in Time of War.

THE economists of great distinction who have presided over this Section of the Association in past years have usually addressed themselves to the discussion of the progress of Economic Science in relation to some problem which had become striking or significant at the time when each meeting was held. It has fallen to my lot to prepare an address at a period when the Empire is involved in a war of tremendous moment both to our country and to the world. Not the least dominant phase of this epoch-making struggle is the economic one; and it is inevitable that, on this occasion, consideration should be given to some of the reactions of this great war upon industry, credit, and finance.

It is both remarkable and significant how silent British economic theory has been upon what may be described as 'the economics of war.' No doubt there are volumes, treatises, and isolated passages which record the effect of some specific war upon prices, or upon credit, or upon the national finances. Or, again, other works may deal with some practical inconvenience which the writer experienced; but, when the total result is estimated, it will be found that by far the larger part of the scanty discussions of this subject are either purely historical or else purely practical. In the vast majority of cases our writers have confined themselves to an analysis of the effects of some specific war on finance and commerce with a view to suggesting measures towards counteracting the inevitable losses, instead of studying the principles of war in general with a view to strengthening the national resources in preparation for future hostilities. Thus, while British economists have said something about former wars, they are almost wholly silent concerning wars to come. This is a fact of immense significance. It demonstrates beyond the possibility of doubt or cavil that in this country there has been no such thing as a mobilisation of economic opinion. On the contrary, our economists can claim with justice that they have been ever on the side of the world's peacemakers, not with false lip-service but through serious and sustained reasoning.

Once Mercantilism began to decline, it is astonishing how little one finds in British economic literature relating to causal relations between war and industry. What there is usually appears as a side issue in some other investigation. For instance, at the end of the seventeenth century, during the eighteenth century, and in the early years of the nineteenth, there was a long controversy over the nature of credit, with frequent digressions upon the character of public debts, which was in effect the consideration of the financing of past wars. In its extremest form one theory represented public borrowings as 'a mine of gold'—a statement which influenced both theory and practice during the eighteenth century. The exaggeration of 'the fund of credit' no doubt seems strange and almost laughable to us now, but it does not differ greatly in principle from the vague popular opinion that a nation can become

* The greater part of the Transactions of this Section were published in book form, by authority of the Council, under the title *Credit, Industry, and the War*, edited by Professor A. W. Kirkaldy. (London: Pitman, 1915.)

richer by increasing its taxes. A public debt as the Midas of the eighteenth century is as much a fairy tale as the modern conception of taxation as a species of 'manna falling on the country in a fertilising shower.' Naturally there was a reaction from the magic claimed for a state debt, and the opposed type of thought urged that supplies, even for war, should be raised during the period in which the expense is incurred. The citation by John Stuart Mill of a passage from Chalmers, in which the latter view is expressed, is almost the only echo of this controversy in more recent times. During the last fifty years, if a few occasional writings, such as those of the late Sir R. Giffen 'On Consols in a Great War,' [1] be excepted, our standard economic works have scarcely anything to say on war, and there is nothing which can be construed into a preparation for hostilities.

But the cultivation of peace by British economists in avoiding the study of the mobilisation of national resources for war has not merely been negative; it was also positive in proving the advantages of peace and the tendency of enlightened economic views to promote it. More than two hundred years ago Sir Dudley North wrote that 'the whole world as to trade is but as one nation or people, and therein nations are as persons. The loss of trade with one nation is not that only, separately considered, but so much of the trade of the world rescinded and lost, for all is combined together.' [2] In the same spirit David Hume urged that 'our domestic industry cannot be hurt by the greatest prosperity of our neighbours.' [3] Before the end of the eighteenth century men of open mind not only recognised that war was a great evil, but also that there was nothing in international commercial relations to cause it or justify it. And so Burke spoke of the condemnation of war as a commonplace and 'the easiest of all topics.' Even victory accompanied by substantial material gains is described by Hamilton as but 'a temporary and illusive benefit.' In one passage he writes: 'The emphatic epithet of "the Scourge of God" has been aptly bestowed upon the extensive warrior. . . . Riches, thus collected, no more resemble riches acquired by industry in advancing the happiness of the nation than the mirth of intoxication is worthy of being compared to the permanent flow of spirits which health and activity confer.' [4] The undercurrent of the work of all the great British economists has been ever on the side of peace. Adam Smith suggested measures to prevent wars being undertaken wantonly.[5] Ricardo shows how free commerce 'diffuses general benefit and binds together by one common tie of interest and intercourse the universal society of nations throughout the civilised world.' [6] It would be wearisome to multiply quotations from the long line of great writers, for already enough has been said to prove that the encouragement of the best possible relations with other countries has always been a prominent feature of their teaching.

This conclusion leads on to the discussion of a new problem. May it not be urged that British economists have been either too selfish or too idealistic—too selfish in inculcating material welfare as an end to the neglect of those national interests which are now seen to be vital, or too idealistic in seeking a cosmopolitan golden age which has proved to be but a dream? That is in fact, have not our economists in their devotion to peace neglected the economic preparation for war? While it is true that the essential teaching of the master minds has been thoroughly pacific, at the same time they recognised that, while war was an evil, both to the world and to us, it was one that might be forced upon the nation. But it would be a dangerous error to conclude from the rare mention of warfare in our economic literature that economists had no ideas upon the subject. Adam Smith has shown with considerable detail that the

[1] *Works*, ii., pp. 189-203. The calculation was that Consols would fall 15 per cent. at the opening of hostilities. The fixing of a minimum price during the first months of the war has made it impossible to confirm or refute Giffen's forecast.

[2] *Discourses upon Trade* (1691), p. viii.

[3] *Essays*, i., p. 347.

[4] *Progress of Society* (1830), p. 411.

[5] *Wealth of Nations* (ed. Cannan), ii., p. 411.
Works, pp. 76, 160.

sinews of war consist of consumable goods.' Therefore, since his time it was recognised that, if war should come, the strength of the nation on the economic side was to be found in the efficiency of its productive system, in the soundness of its credit and finance, and in the success of its schemes of social betterment which provided a vigorous and patriotic population. To have contributed something towards the making of free men in a free land is an achievement of which the economists of this country have no reason to be ashamed. Moreover, with freedom there is the power of initiative and organising ability. And if more than twelve months of war have taught us anything, it is how much modern warfare involves just those qualities of initiative and organising ability which are required for the successful prosecution of industry and commerce. To the economist it must be a matter of profound regret that circumstances have made it necessary to divert these powers from the arts which sustain and brighten life towards causing the evils of death and destruction. Still it is the hard and grievous fact with which we have to reckon; and, to make the reckoning complete, account has to be taken of the genius of our people in which the work of British economists may claim to have some share. We should not be misled by that curious national trait which no foreigner ever completely understands—namely, our inveterate habit of praising the methods of our rivals as if they were unapproachable in their excellence. In the seventeenth century it was the Dutch who were said to be our commercial masters, and very similar things were written later about the French. Therefore, to everyone who is patient enough to look beneath the surface, there is no reason to be perturbed by the commonplaces that are to be found in every newspaper concerning 'the triumphs of German organisation.' No doubt there is very much we can learn from them in systematic arrangement, but what is of first-rate importance is the different spirit that informs the two methods. German organisation involves a mechanical rigidity, and its initiative is severely limited. Ours, on the other hand, is spontaneous and free. No doubt it is slower in starting—often it may seem to us to be painfully slow—but what it can achieve in the end is something greater, for it is the expression of the free soul of a free people. Therefore, for this reason alone, there can be no doubt as to the successful result, for, whether the time required be long or short, the goal of victory must be reached by that nation which can bring initiative to bear upon the economic side of war. And, however much we may have suffered at the beginning from the peaceful habit of mind that limited our preparations to a bare minimum, we have in our industrial organisation, however much at times we may depreciate it ourselves, a wonderfully developed instrument, which only needs to be made available for supplying the almost innumerable needs of modern armies. That there has been delay in making some parts of it available as quickly as was desirable and seemed possible, arose in part from the conditions under which our system has grown up and under which it works. Freedom of enterprise depends to a very large extent on the circulation of rapid and reliable information. British initiative has been accustomed to base its judgments upon data collected from various sources. Modern warfare has introduced secrecy and the suppression of news. This, it appears to me, has been one cause, and perhaps the main one, for the slowness of the adjustment of our organisation to war conditions. Initiative has been deprived of one of the important aids upon which it was accustomed to rely. Therefore the problem, which it is to be hoped is at present in process of solution, is how to avoid the disclosure of information which might be of value to an enemy and at the same time to supply our productive workers with sufficient data to enable them to form accurate opinions as to how their efforts can best help the national cause.

In a country in which the ideal of peace has flourished there must always be a considerable dislocation of industry when it diverts its peace-organisation to the purposes of war. As regards Great Britain that dislocation has exerted its force in two distinct waves. First there was the mobilisation and then the recruiting for the new army, concurrently with which there was the diversion of demand caused by the provision of the manifold needs of the forces. At the beginning of the present year this first change might be described as

' *Wealth of Nations*, i. p. 407.

having approached completion, though necessarily the maintenance of reinforcements involved a steady drain on the number of workers. But in the early summer the campaign for increase of munitions brought about a further dislocation. This was a minor one in point of numbers involved, but it has to be noted that it was likely to produce a disproportionate effect upon industry owing to the normal floating supply of labour having already been used up. When the latter change is completed it is to be hoped that, apart from minor adjustments, the transition will be accomplished and the national industry will be established on a war-basis. The two most critical periods occasioned by war are first the change from peace organisation to war organisation, and secondly the converse change after the conclusion of hostilities on a large scale. Ricardo pointed out long ago that the outbreak of war after a long peace was likely to cause distress and a commercial crisis. The great expansion of credit since the last great war introduced an added difficulty. The improvement of transport and communication has linked the whole world together by tenuous filaments of credit. These had proved sufficient to bear a normal strain, but one must experience a certain amount of apprehension when these delicate threads were rudely hacked and hewn by the sword. The financial interests of the country, like the class of *entrepreneurs*, were confronted suddenly with totally new conditions. The old landmarks were gone, and at first a certain amount of blind groping was inevitable. The leaders in finance and industry were suddenly involved in the fog of war, and the compass by which they were wont to steer proved unreliable. Moreover, the situation was such that quick decisions were called for just when rapidity of correct judgment was peculiarly difficult. The most urgent problem was the maintaining of the credit of the banks amongst their depositors. Here the essential soundness of the credit-system in July of last year was of paramount importance. Credit resembles a highly elastic body: if it is greatly expanded a comparatively slight pressure may cause a rupture; if, on the other hand, it is not unduly distended, it will bear a shock, though with some quaking, which would shatter a more solid substance into fragments. The comparative equanimity of depositors, added to the inherent soundness of the banking system, was a feature of great strength in times which were in the highest degree anxious. The closing of the Stock Exchange and the temporary breakdown of the foreign exchanges made some measure of external assistance from the State essential, though in the future there will no doubt be considerable discussion amongst economists as to the precise form which it should have assumed.

An unexpected outbreak of hostilities is experienced first in the domain of credit, but the disorganisation soon manifests itself throughout the whole range of productive processes. In the general upheaval the normal course of demand is shifted to an unusual extent. That for all kinds of supplies for the forces at once increases, while the consumption of other kinds of goods is subject to considerable fluctuations. Some raw materials are no longer obtainable, having been wholly produced in countries with which communication has ceased, others are procurable only in reduced quantities, while the supply of others was at first uncertain. Again, the state of credit reacted on foreign trade, rendering exporting difficult, and in some cases impossible for a time. All this means that a large diversion of labour and capital became necessary in the first months of the war; and again in the spring of this year the insistent demand for more and more munitions added to the dislocation. With the progress of specialisation in industry there was the apparent risk that such diversion of productive power could only be accomplished at great sacrifice. It would seem that the greater and greater use of specialised machinery, with the corresponding specialisation of skill, would make the change very difficult, and one which would involve great loss of capital and unemployment. After a year of war we see that the latter problem has dropped below the horizon, though it is likely to emerge again on the return of peace when the converse change from war conditions to peace conditions takes place. As regards capital, manufacturers have developed the adaptation of men and machines to certain special purposes. In many cases the demand for the products of these industries has diminished very greatly, and it would seem that the fixed capital must remain either partly or wholly unemployed during the war. Recent economic investigation has shown

that industry not only proceeds by separating processes of production, but also in surmounting the lines of division formerly regarded as distinct. Thus Dr. Marshall has shown that the operatives in a watch-making factory could work the machines used in gun-making or in sewing-machine-making, or in the making of textile machinery.[8] The experience of the early months of the war has fully confirmed the anticipations of economic theory as to the power of transference of specialised capital and labour from one process (for which the demand has temporarily declined) to another (in which it has increased). It is not remarkable that cotton operatives should migrate to woollen mills to make khaki, but it might at first occasion surprise to hear that many makers of brass door-handles soon were at work in helping to produce shrapnel shells—their contribution consisting of the brass driving-rings and copper bands. At the beginning of the winter machines that formerly made spokes for cycle wheels produced knitting needles. Plant normally used to make gear-cases turned out hollow ware tins and basins for the troops. Pen-making factories found new employment in manufacturing military buttons. The list of war uses for plant during the first months of hostilities could be very greatly extended, and the establishment of the Ministry of Munitions has added immensely to the employment of plant for war purposes; but enough has been said to show that economic theory has been proved right in anticipating a large measure of recuperative power in productive processes enabling them to re-employ under the new conditions capital and labour which were temporarily idle. All this is satisfactory for the war period; it must be remembered that on the return of peace the reverse change will have to be made. There may be a short trade boom (arising out of the attempt to restore some of the material ravages of war), but the joint demand from it and from the trades re-opened is likely to be considerably less than the huge present expenditure on manufactures for war. Thus the unemployment occasioned by dislocation of industry through hostilities is likely to be carried forward as a species of suspense account which must be liquidated not very long after peace. Moreover, international credit is likely to re-act on the situation in a prejudicial manner. Even already the financial system of Germany is more strained than appears on the surface. This fact is advantageous to us as belligerents, but it will probably be prejudicial to us not long after the re-establishment of peace. At present much of the inconvertible paper circulating on the Continent does not affect us here. When the inflation has to be squeezed out after the war, a disturbance of credit is not unlikely.

Important as the flexibility of capital and labour have been, the striking success of maintaining our communications within the Empire and with neutrals has been even more remarkable. Steam and wireless telegraphy have had the effect, when supported by adequate naval strength and preparation, of simplifying the protection of maritime trade routes. The events of the early months of the war afford a brilliant justification of the views of many economists of the advantages of diversified sources of supply of food and raw materials from the colonies and foreign countries. The later operations of German submarines against our commerce and even against passenger ships can bring no real advantage to the enemy, and one cannot find words to describe adequately the infamy of the sinking of the *Lusitania*. Some of the destruction of trawlers and drifters cannot pay the cost of torpedoes, that of the rest is at the worst an inconvenience, but in material loss it is incomparably less than the damage of property which is happening every day on the Western battle front when villages and towns are destroyed by artillery fire.

The inestimable services of the Navy in the general protection of sea-borne commerce may be illustrated to a partial extent by reference to the last occasion on which our maritime trade was subject to serious interruption, namely, during the years of hostilities between 1793 and 1815. At that period Great Britain possessed an overwhelming naval superiority, yet freights and marine insurance were often extraordinarily high. For instance, these charges on hemp and tallow from Petrograd to London were ten times the normal rate. Insurance on hemp was 20 per cent. to 40 per cent. of the value. In some cases the freight

[8] *Principles*, p. 339.

and insurance of flax were more than the prime cost. These were moderate rates for that war period. Take the case of silk. It cost 100*l.* to bring a bale of 240 lb. from Italy, instead of the previous rate of 6*l.* These figures seem almost incredible, but they are vouched for by Tooke.[2] Further, they were only a part of the increased difficulty in transport. The delay was remarkable. It is recorded that on one occasion it took a year, on another two years, to send a parcel of silk from Italy to England. Interest on capital and disarrangement of manufacture during the extra period of transit might be estimated to add another 30*l.* to the cost of conveying a bale of silk—that is, 130*l.* against 6*l.*; so that altogether the cost of transport and allied charges increased by more than twenty times the amount paid in times of peace. Such, in bald numerical terms, is the debt we owe to the silent watch and ward of the Navy, which is of equal benefit to our Allies also.

So far I have discussed questions which relate mainly to organisation and transport; but, in summing up our economic position in the present war, the provision of resources by the various combatants will become increasingly important. When Germany cast the sword of Brennus into the scales of international justice she must surely have forgotten the ultimate influence of the wealth and resources of the British Empire. 'To face the world in arms in shining armour' may seem heroic to the Teutonic mind, but it is futile provided that the resources of the world are rightly used against her. This it appears to me is at once our opportunity and our responsibility. War has become so complex that to conduct it upon a great scale demands large capital resources. Our past savings, supplemented by those made during the war, constitute the reserve of the credit of the Allies. No doubt, as in the case of organisation, time will be required to make the full extent of the pressure felt, but it is pressing slowly but inexorably upon the enemy, and as the struggle develops it will press with increasing power. Given the necessary fighting strength of good quality, its efficiency depends upon the extent and adequacy of its supplies. If the struggle be protracted, then victory will rest with the side which can best maintain its supplies, and it is here that our wealth is likely to be a decisive factor. But it must be brought to bear in the right way, and in this respect important functions devolve upon the non-combatant. For many years public and private economy has been a forgotten virtue—too often it came near to being regarded as akin to a vice. Now our ostensible leaders of public opinion are preaching economy almost as if they had discovered a new religion. Such missionary zeal, even though belated, is advantageous. War makes great changes in Distribution; and changes in Distribution, when the general standard of living has been rising rapidly, are likely to lead to extravagance, more especially in war-time when all conditions favour waste. But economy, necessary as it is, can be no more than a step. What is required is the maximum supply of goods, in excess of the needs of the civilian population, which will maintain and even increase the efficiency of the fighting forces. In the summer attention was concentrated on munitions, and this is an instance of our national habit of concentrating on the more pressing aspect of some highly complex problem. The effectiveness of the gunner on a war-ship or of the soldier in the firing line requires the product of the labours of many workers: without the full supply his value as a fighting unit deteriorates. Therefore it devolves upon us to supply such goods both for our own forces, and to a certain extent for some of our Allies also. The effect of public and private economy is to leave more wealth in the hands of the taxpayers, but much of that wealth does not consist of commodities which avail for augmenting the power of the forces. To effect the necessary transformation such wealth must be transferred from the owner of it, either in the form of taxation to the State or in a subscription to a public loan. The Government then arranges for the acquisition of the commodities it requires either by making them here or purchasing them, whether in this country or abroad. In some cases it may be more advantageous to acquire the goods we need from foreign countries by exchanging our own products for them. Now, we already import considerable quantities of food and other necessaries, and therefore our purchases outside this country for war purposes constitute an addition to these imports. Against this we have

[2] *History of Prices*, i. p. 309; *Thoughts and Details of High and Low Prices*, pp. 129, 211.

the profits of our shipping and the income on capital invested abroad and in the colonies. The aggregate of the former is likely to be reduced through the war, and there may be a temporary reduction in the latter through the same cause. Also there are our visible exports and some minor items. Thus it follows that the situation demands as large as possible a production of goods consisting first of supplies for the forces produced at home, secondly the home supply of the necessaries and simpler comforts of life, and thirdly goods to export to pay for our imports of military supplies and of food from the colonies and abroad. And this leads to an important conclusion—namely, that, after the maximum demands both of the naval and military forces for men have been met, there is a plain duty before those that are left. The exigencies of the times demand that there should be no idle class, whether of idle rich or idle poor. We have called out some of our reserves of fighting men, and we must draw also upon our reserves of workers. In the expressive language of our brothers from the Dominions overseas, 'it is up to the non-combatant at home not to let the fighting forces down,' but by his steady and sustained industry to help in providing, directly or indirectly, all the supplies which are required, either in helping to produce these or in making those goods which are exchanged for them. Thus there is a definite duty for every one of us, according to our varied capacities, to take part in a great national endeavour. This is plain common-sense. From the specially economic point of view, war is waste and loss. Therefore it is obvious that we cannot work too earnestly or too unsparingly to bring about as soon as possible the cessation of that loss and a return to normal conditions. No doubt, here again organisation is required. The people are not in a position to judge as to the balancing of the needs for reinforcement, for labour for military supplies produced in this country and for labour to produce goods to be exchanged for supplies or food imported. All the more it becomes necessary for the authorities to strike a balance and to issue clear and unmistakable directions.

All this must seem far removed from the principle of *laissez faire*, the operation of which has become more and more restricted by the mass of governmental regulations and emergency measures. But the people assent to the restriction of their liberty of action under an imperious necessity. Because sacrifices are made in a national emergency, without complaint or murmuring, it by no means follows that the public is learning to love its chains. Unless the war makes a radical change in the national temperament, it would be a political mistake of the greatest magnitude to retain restrictions upon commerce even a week longer than these are unavoidable. In the confused issues of warfare we have the unshakable conviction that we are staking the lives of our soldiers and the whole resources of the British Empire in defence of liberty. It would be a tragedy if, in the defence of liberty, freedom of enterprise and labour were sacrificed, for victory in war would be tantamount to the defeat of our national ideals.

In all the long history of this Association, it has never before fallen to the one who presided in this Section to survey such a scene of ruin and devastation. To the economist war must ever be the pre-eminent instance of wicked waste. One is almost tempted to discuss again that old problem, debated by Bishop Butler—namely, whether whole nations may become temporarily mad. Yet out of all the suffering and all the loss, something that is necessary to the progress of the world must emerge—something that, as things are, can only be won by sacrifice and sorrow. It has happened before in the history of civilisation, and it has now unfortunately occurred again, that it is needful to defend existing institutions from attacks which menace not only these but the possibility of future development. The sanctity of a nation's plighted word must be maintained as a basis for the stability of international relations. One issue which is involved in the present war is the whole basis of international contract. Without being unduly optimistic, one may hope that some compensation for the vast destruction it has caused may be found first in the establishing of treaty rights on a secure foundation, and then that a way will be opened for international agreements which will lessen the risk of future wars. Moreover, the inviolability of public faith is not only of supreme importance in the political sphere, it lies at the root of the whole mechanism of foreign trade and the international money-market. The new 'scrap of paper' theory constitutes a bankruptcy of

external credit. It recoils with crushing force on the nation whose good faith has become suspect, and it produces a feeling of doubt and insecurity throughout the money-markets of the world. When one remembers Belgium, it is not a little remarkable that one of the best analyses of the causes which determine foreign estimation of a nation's credit has been written by a German. I quote the concluding summary: 'These causes are to be found in the opinion which the world holds of a nation's political standards, of the soundness of her institutions, the inviolability of her pledged word, in the last resort of the moral principles which inspire and the intellectual faculties which direct her people's activities.' [10]

Further, from the economic standpoint this war is one which, provided it ends decisively in favour of ourselves and our Allies, should free us from a menace which has faced this country for a generation. At each great epoch in our history, it has been our duty to prevent the wreck of civilisation through the appearance of a new Iron Age with its doctrine that wealth is the prey of the stronger. And so England resisted Spain, Great Britain Napoleon, and now the British Empire confronts Germany in defence of the principle that force must not triumph over law. Indeed, the present strife is perhaps the only issue from a situation in Europe that was becoming intolerable. Year after year the nations on the Continent were proving their devotion to peace by arming to excess, as they said, to defend peace. The burden grew heavier and heavier, diverting national resources from the improvement of the condition of the people and the growth of commerce. Before the war the annual expenditure of the Powers of Europe on their armies alone had increased to about 290,000,000*l*. There can be little doubt that much of this outlay, as well as that on navies, could be saved. It is to be hoped that, when a durable peace has been signed, a very large saving in this type of expenditure will be effected. Moreover, an abatement of military preparations should have another effect in diminishing the drain on productive processes through compulsory military service. Thus, on the whole, while the losses of the war will be enormous, there are some gains, largely of an immaterial kind, to be placed on the other side of the account—namely, security and the re-establishing of international contract, and, of a material kind, in a possible diminution of the burden of armaments, both direct and indirect.

A special aspect of the problems under discussion is the provision of capital for the re-starting of trades contracted by the war and for the restoration of Belgium and other regions desolated during the progress of hostilities. Chalmers, writing a hundred years ago, supposed that in cases of this kind 'in a very few years the recovery both of population and labour would be completed.' [11] The explanation he gave was far from satisfactory even for the time at which it was written, and it is still more deficient as applied to the present circumstances, when in industrial countries fixed capital is much more important than in Chalmers' day. In the last quarter of a century any great catastrophe, such for instance as the partial destruction of San Francisco by earthquake and fire, has been repaired with comparative ease by bringing capital from outside. But the waste of war renders capital exceedingly scarce; in fact, a famine of capital after the war has been predicted. Such an anticipation is over-pessimistic, but capital is likely to be obtainable for a time only with some difficulty. It is to be feared that after the war Europe will experience very considerable straits for several years to come. Not only must the waste of war be made good, but its evil legacy in inflated funded and floating debts must be gradually dealt with, lessening by reason of increased taxation the normal margin for new savings. Increased work and greater economy are the only remedies, aided by improved methods of production.

It is to be hoped that some of the inevitable loss will be repaired in time by better methods of organisation and by an accelerated rate of invention. The waging of a just war results in a quickening of the national spirit. It forces a nation out of the easy and well-worn paths of custom and convention. Thus, out of all the suffering and all the loss, some good will come. The large proportion of our young manhood which has gone to serve the country on the

[10] *On Some Unsettled Questions of Public Credit*, by Prof. G. Cohn, in *Econ. Journal*, xxi. p. 217.

[11] *Works*, xix. p. 141.

seas or in the field, and which returns having looked death in the face without being afraid, will not take up life where it was left. The noble qualities that have been evoked by the stress of battle will remain and will influence civil life during the next generation. The outlook will be both broader and also more simple. Methods of social legislation and administration will become more direct and less timorous. The men who have dared greatly and who have endured will chafe against the rules that have been formed during easier times. Great wars tear away the veils which hide the essential needs of living, and reveal what is fundamental. The directness of vision that has faced danger is not likely to be alarmed in facing the difficulties of our social and industrial problems. And so we may expect with confidence that our legislation will be bolder and also more sane than it has been in the past. The sacrifices of so many cannot pass, when the war is over, and leave no trace. The nation has been re-vitalised in the course of the struggle and the influence of this movement will persist.

In many respects the economic problems that will confront us after the war will be even more serious, and certainly not less difficult, than those of the present time. Still there can be no doubt that these will be faced with courage and patience. The period of stress through which we are passing has shown the unity of thought and purpose throughout the whole Empire. And this, in spite of many appearances to the contrary, will be a great asset in the future. The great national emergency has caused a closing of the nation's ranks, and it rests with us to keep them firm and steadfast when peace returns. There are plain signs that it may not always be easy, since so many industrial and other difficulties have been carried forward as a suspense account which is to be dealt with when the war is over. National unity is enabling us to progress towards victory, and the same unity will be required to enable us to reap the full fruits of that victory at home. It would be a mad waste not to employ the qualities of heart and mind which have been aroused in this great struggle in the service of peace and social progress. The future may be difficult for some years to come, but difficulties are the opportunities of the strong and courageous. It has fallen to us to live in an heroic age; and, if we remain true to ourselves and to our high destiny, we shall have the strength and the fixity of purpose to achieve greatly in peace as well as in war.

The following Discussion then took place :—

Discussion on the Promotion of Industrial Harmony.
Opened by Professor A. W. KIRKALDY.

Sir C. Macara, Mr. W. Thorne, M P., Sir Hugh Bell, Mr. Alfred Evans, Mr. G. Pickup Holden, Professor L. T. Hobhouse, Councillor James Johnston, Rev. P. H. Wicksteed, Mr. G. E. Toogood, Professor Unwin, Mr. B. Ellinger, Mr. R. Walker, Mr. Alfred Smalley, J.P., Mr. A. Lupton, Mr. Glover, and the President of the Section took part.

THURSDAY, SEPTEMBER 9.

The following business was transacted :—

1. *Discussion on Outlets for Labour after the War.*

The following Report, arising out of a Conference held at the instance of the Organising Sectional Committee during the preceding year, and dealing with the Replacement of Men by Women in Industry, was considered :—

Interim Report of the Conference to investigate into Outlets for Labour after the War.

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I.—Introduction.

Conference Committee.

The Membership of the Conference on Outlets for Labour after the War was as follows: Archdeacon Cunningham; Messrs. C. W. Bowerman, M.P., W. J. Davis, J.P., J. St. G. Heath, J. A. Seddon, E. D. Simon; Sir H. Rider Haggard, Sir C. P. Lucas, K.C.B., Sir C. W. Macara, Bart., Sir Sydney Olivier, Sir E. im Thurn; Professor E. C. K. Gonner, Mr. Egbert Jackson Chairman—Professor W. R. Scott, F.B.A. Secretary—Professor A. W. Kirkaldy.

Terms of Reference.

The terms of reference were to investigate into :—

1. The replacement of men by women in industries during the War.
2. The permanent effects of this after the War.
3. The character of re-employment with respect to changes of tastes and physique amongst those who have served with the Forces and are disbanded.
4. The means by which consequent unemployment may be counteracted or minimised.
5. The possibility of employing disbanded men on the land.

It was decided that the best method of dealing with the first two terms of this reference would be to investigate those industries in which the extra employment of women since the War has been most marked, as well as those industries in which there were possibilities of an extension of women's work, with special reference to those trades localised in the London, Manchester, Leeds, and Birmingham districts. The inquiry was commenced in the beginning of June 1915.

For the work, other than in the Birmingham district, through Mr. J. St. G. Heath, who acted as Hon. Secretary, the co-operation of a Sub-Committee under the chairmanship of Professor L. T. Hobhouse, working at the London School of Economics and Toynbee Hall, was secured. This Sub-Committee appointed Mr. E. F. Hitchcock as Secretary, and they wish here to express the debt which they owe to him for his labours; not only was he responsible for the work of organising this part of inquiry, but in addition he prepared the first draft of their Report. The investigators and members of the Sub-Committee were :

Sub-Committee.

Professor L. T. Hobhouse.
*Miss E. B. Ashford.
*Miss D. Austin.
*Miss M. E. Bulkley.
*Miss M. Cross.
*Mrs. B. Drake.
*Miss E. Dunlop.
*Miss A. C. Franklin.
* Mr. F. H. Hamnett.
Mr. J. St. G. Heath.
*Mr. E. F. Hitchcock.
*Mrs. F. W. Hubback.
Miss B. L. Hutchins.
*Miss B. Keen.
* Professor A. W. Kirkaldy.
Mr. J. J. Mallon.
* Miss Moses.
Mrs. Pember Reeves
*Mr. A. Robinson.
*Miss M. Stettauer.
Miss L. Wyatt Papworth.
*Miss N. Young.
Miss D. Zimmern.

* Investigators.

Professor Kirkaldy undertook to organise the investigation in the Birmingham district, especially with reference to munitions and the metal trades. The Central Care Committee of the Birmingham Education Committee, whose Chairman, Councillor Lord, was keenly interested, made it possible for Miss Anne Ashley to undertake the direction of the investigation. Miss Lee, of the Birmingham Women's Settlement, was appointed investigator.

With remarkably few exceptions, and in spite of the pressure of war work in some of the industries investigated, employers, managers of companies, trade union officials and individual working men and women showed great willingness to help on the work of the Conference. Very valuable assistance was also obtained from various women's organisations throughout the country. Thus a considerable amount of useful information was collected, and although, owing to the still undeveloped state of a unique economic situation, statistical data were not fully available, it has been found impossible to compile a Report which, on its descriptive side, refers to new and interesting phenomena which have entered into English industrial and commercial life.

It was decided that the last three terms of the reference could at the moment be more suitably dealt with by papers and discussion. To this end Mr. Christopher Turnor was asked to read a paper on Land Settlement for ex-service

men, and Major Tudor-Craig undertook to give the Section the benefit of his experience on the employment of disbanded soldiers and sailors.[1]

This Report is, therefore, confined to the replacement of men by women in industries as a result of the War, and the possible permanent effects of this replacement. It was finally drafted by the Officers of the Section, who are greatly indebted to the above Sub-Committee and more especially to Miss Ashley and Mr. Hitchcock. The other members of the Conference are not responsible for the details given nor for the views expressed.

II.—Women's Employment during year August 1914 to August 1915.

After a year of war we are able to regard with some knowledge the course which women's employment has taken during that period, and the nature if not the extent of the entry of women into trades and occupations hitherto reserved wholly or partially to men. Broadly speaking, that movement has only just begun (August 1915) to assume any appreciable magnitude. In few industries has the position yet shaped itself. We are therefore at present able to do little else than to indicate the course which industry has taken and roughly to sketch the events which have led during the past year to the present position.

Employment in Early Months of War.

It was clear to the least observant that during the first two or three months of the War a considerable depression had been caused throughout industry, especially among the following trades—dressmaking, millinery, women's fancy and children's boot and shoe making, silk and linen, cigar and cigarette making, the umbrella trade, confectionery and preserve making, cycle and carriage making, jewellery, furniture making and French polishing, the china and glass trades, stationery and printing. In some trades a shortage of raw material or the loss of enemy markets caused a more or less lengthy period of depression. Thus the shortage of sugar caused very considerable unemployment in what was almost entirely a woman's trade—jam-preserving and confectionery. The chemical trade was also affected by the complete cessation of the importation of certain commodities from Germany. The practical closing of the North Sea to fishers brought to a standstill the occupation of those women who are to be found every season in thousands on the English coasts following the herring round.[2] The closing of the Baltic cut off the supplies of flax from Russia upon which our linen trade largely depends, and women's employment in a whole trade was again considerably decreased owing to the lack of raw material. In almost every trade unemployment figures rose to a point only equalled in times of very severe trade depression. The cotton trade was especially hit. Before the War a period of decline had set in, and Lancashire suffered in addition from all the disadvantages incidental to a time of naval warfare. Casual houseworkers such as charwomen and office cleaners, and even skilled domestic servants such as cooks, found themselves out of employment owing to the economies which the public were making. The unemployment of good cooks, however, did not last many weeks.

Distress amongst Women.

The distress caused by unemployment is generally felt more by men than by women, but in the early days of the War the effect of trade dislocation upon women was out of all proportion to its effects upon men. For the women there were few counterbalancing forces such as recruiting. Indeed the full economic effect of the immediate trade depression fell upon them, and the irregular payment of separation allowances at the beginning of the War considerably added to the prevailing distress.

[1] Mr. Turnor is publishing a book which will contain the substance of his address at Manchester. Major Tudor Craig was unfortunately, owing to illness, unable to attend the meeting as had been arranged.

[2] See *Englishwoman*, December 1914, article by J. Haslam.

Revival of Trade.

Happily this state of affairs did not last for long. Very soon the Government came into the market as chief buyer and found industry very willing to concentrate both its labour and machinery upon the production of goods to clothe, feed, and equip armies. The collapse of those trades connected with the normal demands of peace had released thousands of women for other industries, while the contraction of men's employment had been almost wholly counterbalanced by recruiting. In September just under a quarter of a million women, apart from those in non-industrial occupations such as clerical work and retail distribution, were employed, as compared with the numbers in industry at the outbreak of war. The men were fighting and the women had to take their places. From September onwards women—unskilled and industrially ill-equipped as the great majority of them were—poured into the leather, tailoring, metal trades, chemicals and explosives, food trades, hosiery and the wool and worsted industry, which had been suddenly revived by the placing of large orders by the Allied Governments. Between September and December over 130,000 women were drawn into the ranks of industry proper, but still 80,000 unemployed women remained in spite of the net shortage of men, which amounted to about a quarter of a million. Fortunately *the new demand was to a large extent for that class of goods in the production of which female labour normally* predominates.[3] An extension of women's normal employment rather than a displacement of men's by women's labour was what occurred.

Lack of Skilled Labour.

Unfortunately recruiting was carried out without discrimination, and by December the outstanding feature of the labour market was the enormous shortage of skilled men in all industries, a shortage which led to the contraction of women's employment.[4] In some instances employers attempted to train women, but in most cases time was too short, the experiment too risky, and the pressure of business too great, for employers to become enthusiastic over such schemes. Where it was possible to transfer women from one branch of a trade that was slack to an allied branch in which the work was brisk this was done, but there were limitations to such transference. Women were untrained industrially, and, as week by week went by, the lack of skilled men became more and more marked. Through the National Labour Exchanges a Register of Women was compiled and about 86,000 names were enrolled, but only a small minority—4,750—were able to undertake the skilled jobs awaiting them. It must be remembered, however, that a large number of these women were skilled in occupations and professions other than industrial.

By February some of the Government contracts, *e.g.*, clothing, had been reduced, but overdue private home and shipping orders were sufficient to keep the industries affected in a prosperous and busy condition.

Munitions.

The group of trades which showed the most phenomenal increase, in spite of the huge Government contracts which had been already placed, was the munitions group. The story of Neuve Chapelle and the creation of a Minister of Munitions, and the increasing needs of ourselves and our Allies for munitions of war, caused an unprecedented demand in this group. Into the armament branches, therefore, of the metal and engineering trades many thousands of women have been pouring since February. It is as yet early to draw deductions from this further entry of women into munition work,[5] though it is as well to bear in mind that much of the work, *e.g.* shell making, is exceptional work and will diminish when peace is declared.

[3] See separate Reports on Tailoring, Leather, and Food Trades.
[4] See Report on Pottery Trade for exception to this rule.
[5] See Report on Metal Trades, p. 546.

Present Effects of War on Industry.

The women who have entered industry since the War seem for the most part comparatively young. Billeting money and fairly liberal separation allowances have been sufficient to prevent any large number of unskilled married women from returning to work in factories.

One of the tendencies of the War is clearly to transfer a more than normal proportion of the nation's business to large concerns. Though this has its drawbacks the balance on account is probably to the advantage of the women who have entered, as far as the safeguarding of their standard of life is concerned, and consequently of that of the men who will return.

It is clear that the year has seen an enormous upheaval in industry; factories have been adapted to meet new demands and to facilitate women's employment; Trade Union and Home Office restrictions have been relaxed; women are replacing men; experiments are being made and knowledge gained which may well revolutionise many branches of industry. The dominating demand upon industry is that made by the volume of Government contracts. At the end of the War these will substantially decline and industry will begin to resume its normal course. But every transference of labour, every youth put into a man's place, every woman who has received training because of the War, adds something to the bewildering chaos of those industrial problems which will have to be grappled with when peace is declared.

III.—The General Position.

In the earlier months of the War, industry, following the lead of public opinion, organised itself on the assumption of a war of short duration, and a considerable period elapsed before it was generally realised that experiments in the employment of women might have to be made on a considerable and unprecedented scale. The necessity of immediate action in utilising the potential resources of female labour was not understood, and it is now possible only partially to remedy this past error of judgment. Necessity, however, is proving the spur to effort, and experiments and trials are now being made in this direction. Of the results of these interesting developments it is, however, as yet too early to judge. We can only indicate what appear to be the main features arising out of the new conditions of women's employment during the past year.

After twelve months of war three features of the labour market stand out in special prominence:

(1) the serious shortage of skilled workpeople.
(2) the considerable extension of women's employment.
(3) the limited extent to which women have replaced men, in the sense that women are now doing work previously done by men.

(1) *Serious Shortage of Skilled Labour.*

With few exceptions the reports during the last eight months from industries engaged on War contracts eloquently repeat the serious nature of the situation caused by the shortage of skilled workers, due to the number of skilled men who have enlisted and to the changes in industrial methods, which demand a small number of highly skilled mechanics working in conjunction with a comparatively large number of less skilled operatives. Men who in the earlier months of the War joined the Forces have in many cases actually been withdrawn from the fighting front to assist in filling the gaps caused by this deficiency in the ranks of industry. There is no lack of unskilled workers, but the extent to which semi- or unskilled labour can be employed depends not only upon the amount of that labour available, but upon the extent to which skilled labour can be obtained. In the case of the men who remain the lack of training and experience is all too general; amongst women it is, with rare exceptions, the universal rule. Apart from other disabilities this factor alone has been sufficient seriously to limit the entry of women into those industries in which there are enormous demands for materials of war. Not only have the majority

of women, owing to their lack of training, found it impossible to take up skilled work in these trades, but, as stated generally above, the absence of skilled workers amongst them has in its turn proved an almost insuperable obstacle to the employment of any but a small proportion of the great waiting army of willing but unskilled female labour. This *shortage of skilled labour is the cardinal feature of the industrial position with which the nation is now faced.* It is true that by minor adjustments in the organisation of the trades concerned the entry of a few extra women can be facilitated, but the situation in its broad aspects seems almost insoluble during the present time of war. Certainly in a great many industries women are working on processes previously wholly or partially done by men, but the extent to which this is the case is inconsiderable. The margin of difference, however, between actual fact and possibility is yet to be discovered.

(2) *Extension of Women's Employment.*

It is impossible with any accuracy to give figures indicating the extension of women's work since the War. The trades in industry proper in which the extension of women's employment has been most marked are engineering, chemical trades (explosives), leather work, tailoring, meat preserving and grain milling, basket (shell) making, elastic webbing, scientific instrument making, brush making, electrical engineering, canvas sack and net making, leather tanning, rubber work, hosiery, hardware, wire drawing, tobacco, boot and shoe trade, shirt making, wool and worsted, silk and jute trade. Excluding the munitions branch of engineering, the extra employment of women in these trades probably does not exceed 100,000, and four months ago was little more than half that number, compared with the same month in the previous year. A small proportion of the extra women employed in these trades are, however, doing men's work, the probable reasons for which are discussed on p. 514 *seq.* Generally speaking, the extra employment of women in any branch of industry proper has been effected by transference from trades that are depressed or from branches of the same trade which are slack to those that are brisk.

A marked acceleration in women's employment has also taken place *in non-industrial occupations* such as shop assistants, bank clerks and in other forms of clerical work, waitresses in hotels and elsewhere, and certain classes of railway work. In these occupations women have probably replaced men, in the sense of doing men's work, to a greater extent than in industry proper. The supposed social status of an occupation rather than its pecuniary gain appeals more generally to some women than to most men, and many women who find their home surroundings somewhat dull and a shop counter or an office stool comparatively attractive would never consider entering a factory or a workshop. Consequently we find that for the most part women who have entered industry proper since the War have had previous industrial experience in other trades, and that where they have not been wage-earners previously they have been attracted in a great many cases to the more 'lady-like' occupations. Patriotic motives have, however, supplied a stimulus to a number of women to enter industry. Those branches concerned with the production of munitions and direct war supplies have proved especially attractive in this respect.

The relaxation of Trade Union and Home Office restrictions has also had the effect of extending women's employment. Where a shortage of male labour has been apparent the trade unions have in many cases—*e.g.*, in the leather, engineering, and metal trades, wool and worsted trades, &c.—agreed with employers that, for the period of the War only, women may work on processes which were previously done wholly or partially by men, on the condition that the wage rates paid to the women shall be the same as those paid to the men. The relaxation of Home Office regulations has only been made on applications in particular cases, and is mostly connected with the extension of overtime.[1] Many of the trades in which the War demands have been extensive normally employ a larger number of women than men, and in these the extension of women's employment has been considerably accelerated by the War.

[1] Vide *Board of Trade Journal*, July 8, 1915.

(3) *Replacement.*

From the fact that fewer men and many more women are now in industry, there is a prima-facie case for supposing that women have replaced men in the sense that they are now doing processes which before the War were done by men. Our information, however, shows that this is not the case, save in special instances and to a limited degree.

The one important factor upon which the prosperity of industry depends to-day is the virtual monopolising of the market by our own and the Allied Governments. It will be interesting to consider whether the War demand is not on the whole a demand for a class of goods in the production of which a greater proportion of women rather than men can be more usefully and economically employed than under normal peace conditions. The nature of the demands arising out of the War must have an important bearing upon the kind of labour required. A large part of the Government demand for goods is in those branches of trades in which a larger proportion of women are employed than in the trade as a whole. A good example of this is the tailoring trade, which normally employs something like 130,000 women, together with a large casual fringe of women who come into the trade in times of seasonal pressure. This trade illustrates the point at issue, though it will not, of course, be taken as typical of all industry. The retail bespoke branch, in which high-class tailoring work is done, employs men almost entirely, and since the War it has been very depressed, for the demand for 'high-class' work has been much reduced. The clothing of a soldier is good but not 'high class' in the sense in which a Bond Street retail bespoke tailor might use that term; it is tailoring done in the medium branches of the trade in which female labour normally predominates. This part of the trade has drawn women and girls from its other branches and from its fringe of casual labour as well as from other trades in which there was a surplus of female labour. It thus shows a great increase of female labour since the War which has been drawn in, not to undertake work previously done by men, but merely to cope with a huge increase of orders in that branch of the trade in which a larger proportion of women than men is normally employed. Again, the cloth from which the uniform is made is not the very finest suiting, and the huge demands upon the wool and worsted trade for it have resulted, as in the tailoring trade, in a larger demand for female labour compared with the demand for male labour than the trade as a whole would normally employ. The great increase of women's employment since the War in the leather trade has to a certain extent been in the lighter accoutrement branches on processes normally done by women, while in the boot and shoe branch there has actually been a replacement of women by men owing to the heavier nature of the work required in the military than in the civilian boot.

A considerable part of the Government demand is also in trades, *e.g.* the munition branches of the engineering and metal trades, in which a large proportion of semi-skilled or unskilled female labour can be absorbed especially in such exceptional processes as the filling of shells, and in which after the War the demand will decline.

From the above considerations it will be seen that *much of the extension of women's employment during the War in industry proper is in work which is normally done by women and in which the necessities of war have created an unprecedented demand. Other work now done by women is exceptional work which will decline with the advent of peace. But a survey of the whole field suggests that, owing to the installation of special plant, the proportion of woman labour may be affected.*

But though women are not as yet to any considerable extent doing the work of men or undertaking highly skilled jobs, they are undoubtedly slowly undertaking processes in many trades which were previously thought *just* above the line of their strength and skill. This is seen particularly in leather, engineering, and the wool and worsted trade, and also in trades which, though depressed since the War, have yet experienced a shortage of certain forms of labour, *e.g.*, pottery, cotton, and the printing trade. This shifting of the line of demarcation between men's and women's jobs has in many cases received

trade union opposition, though in most cases agreements have been made for the duration of the War only and without prejudice to the consideration of the question after the War. In this connection it would be interesting to consider in how far trade union restrictions, especially those concerning the entry to the trade and the period of training required, are based upon the conditions which prevailed in the past or upon the realities of the present. Employers are, however, reluctant to express opinions until more experience under the new conditions has been gained.

In non-industrial occupations, such as clerical work, in certain forms of railway and vehicle work, such as ticket collecting, carriage cleaning, and tram and 'bus conducting, in various forms of retail distributive work inside retail shops as well as outside work like van driving and delivery, and in warehouse work such as packing and despatching, women have, however, replaced men, in the sense of doing work previously done by men, to a much larger extent than has occurred in industry proper. The majority of firms, when faced with a shortage of male labour, have first commenced to replace men by women in their office and warehouse staffs. Clerical work is obviously suitable for women, and employers have had far less hesitation in introducing a greater proportion of female labour into this side of their business than into the industrial side proper. The conditions of the clerical labour market, including as it does a great majority of clerical workers who belong to no trade organisation, have made it easier to introduce female labour without encountering serious opposition from the Trade Unions concerned than in those trades where the group of workers is smaller and the workers are more highly organised. Enlistment has also been exceptionally heavy, in some cases over 30 per cent., among men such as clerks, whose occupation is sedentary, and, in spite of the restriction of business, the net shortage of men was soon apparent, and women, mostly young girls from school or middle-aged women from professions which have been hit by the war, were rapidly drawn in to make up the shortage. Into Government departments, local authorities, banks, insurance and other offices, as well as ordinary business houses, women are being utilised in increasing numbers to do work previously done by men.

Into most of these occupations women have entered to do work either slightly more difficult than that done by women before or else work entirely new to them, such as railway and clerical work in banks. In very few cases, however, is the work now done by women exactly similar to that previously done by men. Obviously, the lack of training and experience, together with natural disabilities of physique, make certain forms of work and conditions of labour impossible for women which are possible for men. Thus, in the case of ticket collecting, in which at first sight men's and women's employment appear equal, it is found on inquiry that the women work shorter hours, requiring three shifts to do what men do in two, and their shifts are arranged when traffic is less heavy, thus leaving the more arduous work to the men. In many of the large stores three women are required to do the work formerly done by two men. It is as yet too early to form final judgments until women have had time to adapt themselves. Until August 16, 1915, the extra women employed since the War on railway work had been paid less and given lighter and shorter work than the men. Since that date, however, the railway companies have agreed that women shall be paid the same rates as the men, and, in consequence, given similar work. It will be interesting to discover how far women will successfully compete with men in this work now that the conditions are approximately equal.

Both in industry proper and in non-industrial occupations women have often been introduced to do the work, not of the men who have enlisted, but of boys and youths who have been promoted to do the work formerly done by men which was of an arduous nature or required special knowledge which in part the youths have already picked up. Young girls have replaced boys as messengers, etc., and young women have taken the places of youths. It was often remarked by employers that girls are found generally more efficient, careful, and conscientious than boys, and apart from work entailing physical strain, such as the carrying of heavy parcels, are much to be preferred to them; on the other hand, the majority of employers considered that adult women are less efficient than men.

Readjustments in Industry.

Considerable attention has been devoted by some employers to the further subdivision of process and grading of labour as well as the introduction of mechanical and other readjustments in order to facilitate the employment of women.[7] Men's work has generally been that requiring more *strength* and more *skill* than women's work and a greater differentiation of process as between skilled and less skilled, lighter and heavier work, has made possible the further employment of women in processes in which their economic value is equal to that of an average man. In some cases this specialisation of function is opposed by organised labour, as in the case of the cotton trade and railways,[8] among other reasons on the ground that the readjustments result in the wage rates of men remaining the same while the arduous nature of the work they have to do is increased.

In this connection one point has come out somewhat forcibly. Throughout most trades the extent to which up-to-date machinery and efficient organisation have been introduced differs to an extraordinary degree as between different firms. One firm will have introduced methods and machinery which in another firm have not even been considered. To this lack of knowledge and initiative is due several of the difficulties experienced by some employers in extending women's employment and releasing men. In normal times practical opinion suggests that extreme specialisation may be a questionable advantage, as possibly sacrificing quality to output. Skilled labour is so scarce owing to the War that employers have necessarily to economise it. The present demand is abnormal, but it shows the necessity for giving serious attention to the training of skilled mechanics.

The Training of Skilled Labour.

A time of war is the time especially when the preparedness and fitness of a nation is tested, and this applies to industry as much as to other more militant activities of national life. The dangers of an insufficient supply of skilled labour revealed by the present crisis have opened our eyes, as probably nothing else could have done, to the importance of industrial training both in its immediate and its permanent aspects. Experiments in the training of women for industry and business are now being increasingly made to meet present demands.[9] In spite of the special circumstances these developments have as much a permanent as a temporary significance, and some examination of the more permanent aspects of the problem may therefore be of value.

It is obvious that the training of women as skilled workers depends upon

(1) Circumstances, common both to men and women, relating to the organisation of industrial training.
(2) Psychological, physical, and other conditions in which men and women differ. These are discussed in Section IV.

(1) The fact that many industries at present offer employment to large numbers of unskilled workers of a nature which can be learned in a few weeks'

[7] See Distributive Trades, page 525.
[8] See pages 530 and 566.
[9] The Interim Report of the Central Committee on Women's Employment (Cd. 7848) contains some interesting suggestions on the promotion of new openings for the permanent employment of women. Little of a practical nature has, however, yet been done, although the suggestions made extend to the following trades : Toy making, artificial flower making, and the making of baskets, bonbon bags, hair nets, memorial wreaths, nets, polished wood fancy articles, potash (from seaweed), rugs (of a kind previously made in Austria), slippers, stockinette knickerbockers, surgical bandages, tapestry, and tinsel scourers, and also gold beating, the weaving of willow and rush for mats, chairs, and baskets, and the cottage weaving industry. In these occupations little opportunity occurs for displacing men by women; they are mostly small industries in some of which it was suggested that advantage might be taken of the cessation of enemy competition.

time has not been altogether favourable to the training of the skilled worker. If a boy or girl can become a productive worker almost at once, it requires a special knowledge and self-control on his or her part to remain in the position of a learner with a learner's wage for years, in order to become a skilled artisan. Nor are the steps by which young workers may climb to this position made clear to them or to their parents. It is of great importance that they should be shown clearly that training is for their own advantage, and that it is on training that the ultimate scale of their pay and security of their work depends. This may be effected to a great extent by the juvenile branches of the Labour Exchanges co-operating with the Care Committees of Education Authorities. Employers could assist by making clear to every beginner the possibilities for advancement, and by doing so would probably build up a more stable working force.

The decay of the apprenticeship system, which has proceeded with especial thoroughness during the last thirty years, and the recent changes in methods of production and especially the increasing introduction of machinery have, it may be feared, given rise to the impression among many parents that it is useless for their children to be trained as skilled workers. Skill is needed now, as it has ever been, but the type of skill required changes so rapidly as to make industrial foresight very difficult, especially to the young workers and in a lesser degree to the firms which employ them. Even where there is formal apprenticeship, or the definite status of learner, a good deal of time is apparently wasted during the first few years of training, not only in promiscuous fetching and carrying, but in processes which become obsolete during or soon after the period of training. According to the opinion of some credible witnesses, systematisation alone would shorten by some 30 per cent. the long term of apprenticeship demanded in certain trades.

The relative functions of the technical school and the workshop in the training of the artisan must vary according to the trade, but there are three main directions in which development is desirable.

(*a*) The further establishment of full-time Technical and Trades' Schools, working *in close co-operation with the trades concerned* and making a special study of the most recent developments in technique and the future prospects of the several trade processes.

(*b*) The development of part-time Continuation Schools, and of the practice of permitting young employees to attend during working hours, in view of the generally admitted failure of evening instruction at the end of a day's work.

(*c*) A workshop training systematised and reduced to the shortest period compatible with efficiency. In some trades this might take the form of a modified apprenticeship adapted to the needs of the time. This should be subject to frequent modification with the alteration of processes, so as to ensure that the apprentice is not required to make sacrifices more than commensurate with his or her gains. In some trades, however, a systematic promotion from one department to another would probably be possible without formal apprenticeship.

(2) In the metal working trades, especially, and this is also true of some others, all the highly skilled workers are men. The women employed in these trades are either semi-skilled or unskilled. The question arises whether women are capable of becoming highly skilled workers, and if so, whether they would in normal times be preferred to men. This depends on a variety of circumstances, physical, psychological, economic, and social. Some employers in the more skilled trades, *e.g.*, engineering, express a doubt as to whether women could be trained to the same degree of skill as has been attained by highly skilled men, maintaining that women lack as a rule the necessary qualities of judgment and initiative, and dislike shouldering responsibility. This point of view was often expressed in less skilled trades. Other employers expressed different views on these points, being convinced that in time women would be able to attain the skill and initiative of the best men workers, provided the work which they were expected to do did not entail too great a physical strain or was not in other ways harmful or objectionable to them. The

majority of employers, however, seem to be agreed that women generally prefer mechanical and routine employment.

In spite, however, of the view which we have found to be prevalent among the majority of employers, experience is teaching that given the opportunity women can produce work which, in spite of their lack of industrial experience, compares favourably with similar work done by men. In some engineering shops where every facility has been given to women to undertake new work involving some judgment and skill their work has reached a high pitch of excellence, and has been little inferior in output to that of men. Hitherto in engineering women have been employed almost entirely on 'repetition' work. During the past few months, however, considerable and far-reaching changes have been effected which are likely to have a very marked effect after the War. In a factory which is engaged in the production of projectiles up to 4·5 in. a new department was started a short time ago, the workpeople being women, under the direction and supervision of a few expert men. Though the majority of the women were raw hands totally unaccustomed to tools it was found that within a few days their work attained the necessary accuracy. Much of the work demanded intelligence of a high degree. The women have shown initiative as well as manipulative dexterity—*e.g.*, in a certain screwing operation it was customary, before the employment of women, to rough the thread out with the tool and then to finish it off with taps. Some trouble having arisen owing to the wearing of the taps, the women of their own initiative did away with the second operation, and are now accurately chasing the threads to gauge with the tool alone.[10] This is work of which any mechanic might feel proud. Within the past few months women have also undertaken heavier work than was previously thought possible. They are turning out 18-lb. high-explosive shells and Russian 3-in. shrapnel, work involving twenty-one operations, all of which are now done by women. On the delicate work necessary for time fuses they are found particularly suitable. Women need encouragement and sympathy in their new surroundings, and the ordinary male workshop attitude is not one in which their best powers and abilities are encouraged. The standards of the past are too apt still to bar the way to the encouragement of women's employment in other than mere mechanical work. Skilled workmen are sometimes selfish and employers prejudiced, and this attitude may postpone the substitution of women for men in some cases. Examples such as those given above are not frequent, but they indicate something of the possibilities of the replacement of men by women, especially in munitions, where women are increasingly needed.

IV.—Possible Limitations to the Industrial Employability of Women.

From what has been said before it will be obvious that, the customary barriers to the employment of women having broken down, the chief factors remaining are the fitness and willingness of women to undertake industrial work. In the past the obstacles to women's employment have been

1. Women's lack of physical strength and staying power as compared with men's. Lack of physical strength effectually bars them from undertaking work entailing any considerable physical strain. In some cases the work has proved injurious to them, *e.g.*, the carrying of heavy weights in warehouses. In the printing trade it has been suggested that women should do 'laying on.' As this often involves the handling of heavy rolls of paper the process is really prohibitive to women unless it can be subdivided and the heavier work given to the men.

   It is stated that women are less reliable than men owing to more frequent absences on account of illness. Figures supplied by certain insurance companies show that between the ages of 21 and 40 women's absences are 15 per cent. as against men's 5¾ per cent., though below 21 years of age there is hardly any difference. In this connection it should,

[10] Quoted from *The Engineer*, August 20, 1915.

however, be remembered that the lower wages of women and the double strain imposed by their home duties often react upon their health and increase the natural sex disparity.

2. Certain forms of work are believed to be bad for a woman's character or debasing to her taste, making her less fit to care for and train the next generation. Here the problem is more difficult, and where these difficulties are real[11] improvements could probably be made in conditions and hours of work. It may be suspected that, in many cases, conditions which are morally or intellectually bad for women are not altogether beneficial for men!
3. The comparative shortness of women's industrial career has led employers to regard time given to the acquisition of technical knowledge by women as wasted. The young girls employed make up so large a proportion of the total amount of female labour that it is customary to treat them as if industrially they never grew up. In most trades there is a certain amount of work requiring more experience, which absorbs the comparatively small proportion of women who do not marry, or who remain permanently in industry after marriage.

   Since, unfortunately, for some time to come it seems probable that the female population will be more in excess of the male even than in the past, the number of women who remain on the labour market all their lives is likely to be increased. Already it is stated in some works that during the last year promotion has been very slow because of the comparatively small number of marriages. Industrial ambition among girls is, therefore, becoming very desirable, and experiments in their industrial education are likely to become increasingly necessary.
4. Women in the main do not regard their occupation as their life's work. The industrial value of a woman is minimised by the probability of her marrying, and in the majority of cases her consequent withdrawal from the trade. In any case it is stated that her attitude to marriage causes her attitude to her work to be less stable than that of men. In many trades it is said that women require more supervision than men, owing to what appears to be their lack of initiative and timidity with regard to responsible work. They are less ambitious and more content to remain in positions which make comparatively little demand upon them.

In less skilled work, however, women are often in many respects superior to men. A woman is generally a more cheerful worker and does not feel to the same extent as a man the monotony of performing some small operation during long hours at a stretch and week after week. Women are also traditionally more sober and patient than men. Both employers and workpeople speak with admiration of the patience of women. This patience is no doubt partly due to the fact that most women do not expect to be employed industrially over a period of many years.

It is difficult to dogmatise upon the attitude of woman to industry and still more to prophesy as to her attitude in the future, but, generally speaking, it is not incorrect to say that heavy work and work requiring great physical strain are debarred to woman because of her lesser physical strength and stamina. Secondly, her attitude towards marriage is essentially one of the realities to be faced. Whether woman comes into industry on greater terms of equality with man as far as training and continuity of employment are concerned depends largely upon her own inclination in the matter, though changed economic and social circumstances may force a still larger proportion of women into the labour market. How far she will be able to compete with men will be determined by her attitude and the natural disabilities which press all too unfairly upon her in competing with men in industrial life.

The above conclusions, which are based upon the opinion of employers and others whose past experience enables them to judge of the suitability of women for industrial employment are not intended to be in the nature of any final statement of the limitations to women's employment. They attempt to indicate the difficulties which have beset women's employment in the past, and though

[11] See pp. 510, 511.

many of them will obviously remain, some will no doubt be considerably modified, especially if the women concerned are sufficiently anxious to overcome them and to enter and remain in industry on more equal terms with men. Already within certain spheres some of the possibilities of women as organisers and skilled workers have been demonstrated by numbers of trained and educated women; with further education and training and a greater freedom to work out their own economic destiny it does not require a vivid imagination to picture a state of things differing in many essentials from some of the realities recorded above.

V.—Wages.

The question of wages is at once the most controversial as well as the most complicated question of women's employment. Roughly, women receive 50 per cent. to 75 per cent. of the wages paid to men in similar occupations. This at first sight would appear an injustice. But the conditions must be thoroughly understood before it is possible to dogmatise. A mere statement of the comparative wages of men and women without mention of the attendant circumstances is useless. And as far as this Report is concerned it has been difficult in the time at our disposal to collect all the facts necessary for a thorough consideration of the question. We can, however, indicate some of the chief factors from the point of view of both employers and workpeople.

Reasons given for Low Wages of Women.

Employers are apt to regard the question of wages from one aspect only—that of paying to the individual worker what in the employer's opinion he or she is 'worth.' Men's Trade Unions and many of the women's organisations, on the other hand, object to the payment to women of lower rates than those paid to men for similar work. In some cases the policy of the men on this point is opposed to that of the women in the same industry—the men asking for equal rates for men and women, and the women objecting on the ground that this would lead to their effectual exclusion from the trade.[12]

The limitations to women's employability stated in the preceding section must be borne in mind in a consideration of the question of wages, as they have a direct bearing upon the question of women's output as compared with men's.

Though women are often paid the same piece rates as men when the work is similar, they are very rarely paid the same time rates owing to their lesser output. In addressing a deputation of women on the subject on April 13, 1915, Mr. Runciman stated that in this matter the Government intended to follow the practice usual in private industry—'in replacing men by women we have provided that under Government contracts the same piece rates are to be paid for women as for men, and in regard to time rates no special conditions have been laid down.'

The reasons given by employers why the wages of women are lower than those of men may be divided into two groups. The first group depends upon those causes stated in Section IV. and resolve themselves briefly into

1. Women can perform only the lighter processes.
2. The output of women is less than that of men.
3. Women are less skilled and experienced than men and are rarely willing to devote much time to training even if employers thought (as they rarely do) that the short duration of their industrial life justified a long training.
4. Some conditions, such as night work, are more objectionable in the case of women than of men.

It should be remembered, however, that a man's wage in the earlier stages of his industrial career is reckoned in two dimensions—the size of the wage and the prospects of promotion and higher pay after a period of training or experience. A youth often starts at a nominal wage and gives a part of his

[12] See Report on Cotton Trade, p. 565.

services for a period of years on a tacit understanding that later he will be able to obtain a rapid and substantial increment of wages. In the case of a woman, however, assuming that her industrial career is shorter than the average man's and that in the majority of cases she has fewer prospects and is only employed for her intrinsic output, it would seem only equitable that, other things being equal, a woman's wage in the earlier stages, instead of being lower than that of a youth doing the same work, should be on a higher scale.

In comparing men's and women's wages it is further necessary to discover how far the work done by each is substantially the same. Even during the present time of stress, when women are to a certain extent doing work which would normally be done by men, the work, as shown in the detailed portion of this Report dealing with separate trades, is very rarely similar either as regards process or conditions. With the introduction of women the work has often to be subdivided, and the men generally have at least the arduousness of their work increased with ofttimes the addition of overtime and night work and a larger amount of work entailing a greater strain. Where workshops have been recently built for women workers they have been equipped with machinery of a very different type from what would have been installed had the management been able to procure skilled men. Whilst women can readily be trained to work such tools as capstan lathes without any great difficulty, a long training is necessary in operating other tools for producing the same fittings. In many of the textile trades it is found that where men and women work the same machines the work is unequal, as only in rare instances can the women 'tune' or 'set' their machines. The assistance of a male 'tackler' is required, and time is lost as well as extra expense incurred. The apparent simplicity of the 'equal pay for equal work' test is in practice found to be extremely complicated and difficult to apply.

Social Custom.

The second group of reasons advanced by employers for paying women at a lower scale of wages depends more upon custom and social outlook. Thus many employers excuse the lower wages of women on the ground that the needs of women are smaller than those of men. It is argued that a man's wages has normally to be used for the support of a household, while a large proportion of working women have only themselves to support. Some employers also state that as women ask for less wages than men they are paid less in consequence. Others follow social custom in regarding women workers as of a lower status than men.

These reasons are apparently regarded as adequate and conclusive by many employers, but they are looked upon by representative working-class opinion with great suspicion. Our evidence goes to show that the difference between the wages of men and women is often more than can be justified by any difference in efficiency, and that this has the result of making it profitable for a firm to introduce the largest possible amount of female labour. For the most part Trade Union (male) opinion agrees that on the basis of 'to everyone according to his needs,' the lower wages of women might be justified, although they believe that the low demands of women workers are partly the result of lack of organisation and of industrial ambition among them. Whether, however, payment of a lower wage to a woman be unjust to her or not, the Trade Unions maintain that it is unjust to the man whom she is thus able to underbid.

In this connection it is only fair, however, to state that the evidence of some employers goes to show that where they have replaced men by women their wages' bills for the same output have been greater than when they employed men only. Often two women have had to be employed instead of one man, and three women instead of two men is a fairly common occurrence. This, of course, only illustrates the familiar contention for which in recent years the Trade Boards Act has supplied additional proof, that low-paid inefficient labour is by no means 'cheap' labour. Many of the best employers recognise this, and for this reason are not always anxious to replace trained men by untrained women. But when a greater subdivision of processes is introduced the employment of women at lower wages is frequently found to

reduce the cost of production. Some employers, *e.g.*, in the leather and small metal trades state that they have been able to introduce female and other unskilled labour by means of modifications in their methods. Skilled workmen are thus in some cases undercut in the labour market as effectively as though women offered to do equal work for a smaller wage.

Fair Wages.

It is too generally assumed that the Fair Wages Clause included in all Government contract agreements sufficiently safeguards the standard of wages paid to women on Government work and secures to them a fair wage. This, however, is not necessarily the case. The Fair Wages Clause is framed apparently on the assumption that in the trades to which it applies standard recognised rates of pay can readily be ascertained. In the same trade, however, very considerable diversities in methods of work and division of processes often exist which render the fixing of rates an extremely technical and complicated matter, necessitating the existence of highly organised machinery representative both of employers and workpeople. These necessary conditions are to be found least of all in those trades which employ large numbers of comparatively unskilled women workers, and in such trades the Fair Wages Clause, save in most flagrant cases, is in consequence practically inoperative.

Certain of the worst-paid women's trades in which very large contracts have been placed during the War, *e.g.*, tailoring, shirtmaking, and food trades, are scheduled under the Trade Boards Act, and though the results of this Act have been very considerable in raising the standard of piece-work rates in those trades, the securing of 'fair' wages to *all* workers concerned is outside the powers of the Act. The Act can only secure that the piece-work rates paid are such as yield to an 'average' worker not less than a certain fixed time rate. Adult women who since the War have transferred temporarily from depressed trades to those which are booming are often for the purposes of the Act classed as 'learners' and employers need only pay them according to the learners' scale of wages, *e.g.*, a woman over twenty-one years of age who before the War earned 15*s.* per week as a bookbinder transferred in December last from her own trade which was slack to tailoring in which there was a great demand for women's labour. She was engaged in a process of 'finishing,' known as 'cleaning'—an unskilled process in which the necessary rapidity could be attained in about two days. For this an ordinary worker should have been paid for a fifty-five hour week at least 14*s.* 10¾*d.* Her employer, however, obtained a learner's certificate in respect of her from the Office of Trade Boards, and after paying her on the learner's scale, *i.e.*, 7*s.* 5*d.* per week, for eleven weeks, dismissed her as the volume of Government orders had decreased and she was no longer needed. In another case a Government contractor sub-contracted a large proportion of his contracts to small workshops at a rate which made it impossible for the sub-contractors to pay fair rates to their workpeople. Under the Trade Boards Act it was impossible to prosecute the contractor. These two cases are typical of many.

VI.—The Woman Worker after the War.

Forecasting is usually most unsatisfactory, and in the present stage of transition would largely resolve itself into guesswork. Extremely interesting developments of women's employment are likely to occur within the next few months, but as yet they are little more than in their incipient stages and it is not the business of this Report to anticipate their results.

Attitude of Employers to Men Returning after War.

It has been, however, interesting to gather from employers their ideas as to the policy they intend to pursue after the War with regard to the men who will return. Much will depend upon the industrial and economic position and the rate of discharge from the Army. We have found that employers almost

unanimously state that it is their intention to take back those of their former employees who return, not necessarily in their former positions, but at any rate in positions not inferior to those which they left, and in many cases definite promises have been given. In some cases—*e.g.*, the railways—the men have been promised to be taken back not only in their former positions, but in those to which they would in the natural course of things have been promoted. The change of taste and outlook will be a factor which after the War is likely to discourage some men from returning to their old positions. One large retail drapery store from which many men went during the South African War states that of those who returned to England only 6 per cent. wished to return to their former occupations. The problem then was of course insignificant compared with the present, and the instance given merely illustrates a factor which many employers feel will prevent a considerable number of men from returning to the workshop and bench and especially to the office.

In some cases of course the experience gained during the War has shown that certain jobs, *e.g.*, lift attendants, can be as efficiently done by women as by men. In such cases employers intend either to take back the men who return and as they are promoted or fall out of industrial life to substitute women in their places, or else better jobs will be offered to the men and the women will be kept on. It is probable that when girls have replaced boys in blind-alley occupations they are likely permanently to remain, as they have proved in most cases more efficient and reliable and are likely to remain longer.

Attitude to Employment of Women after War.

With regard to the women the problem appears to have been very little considered, most employers treating the extra employment of women as a purely temporary measure to be dropped on the conclusion of war. When friction has occurred with the trade unions with regard to the replacement of men by women an agreement has generally been arrived at in which the employer has promised to take on women for the duration of the War only. The general attitude to the women, therefore, is that at the end of the War they will be dispensed with.

It has before been noted in this Report that, as far as the present position is concerned, women in industry proper for the most part have had previous industrial experience. They have either come from trades which are depressed owing to the War, or from other branches of the same trade in which work was slack, or they are in a few cases married women returned to the trade, or else belong to the fringe of casual labour with which too many industries are badly embroidered in times of peace. Those who have been drawn from other industry will no doubt return as their trades revive and the others will return to their normal occupations. In non-industrial occupations, with the exception of railways, a large number of the women are likely to remain after the War.

Permanent Increase of Women's Labour after the War.

The great increase of women's employment can hardly fail to have permanent results, especially in non-industrial occupations such as clerical work and the retail distributive trades, where for many years a considerable increase of women's employment has occurred, these trades being peculiarly suitable for the further employment of women. It will probably persist in those manufactures where the processes are minutely subdivided and repetition work predominates. The newly built munition factories which are staffed by women may continue to be so staffed, if it is possible after the War to employ them on some product other than munitions. Where female labour is either underpaid or is obviously superior to male labour, a special inducement offers itself to employers to retain the women, and no doubt this will result in a number of the women remaining after the War.

We may, therefore, anticipate that after the War the proportion of women in industry will be greater than before and the competition of men and women will increase. In order to minimise the bad effects which may result the following measures suggest themselves:

1. The extensive emigration of women. At the close of the War a considerable proportion of the men discharged from the Army will have acquired a taste for an open-air life, and may prefer the prospects offered by the Colonies. Unless, therefore, the respective sexes are to be distributed over the Empire even more unevenly than at present, steps must be taken to ensure the emigration of women in something like the same proportion as that of men.

2. The better technical training of both boys and girls. There seems little danger of a superabundance of highly skilled labour. It is the experience of all trades that, except in processes which have been superseded, the supply of highly skilled workers is usually less than the demand. If the material wastage of the War is to be repaired, the need of the country for skilled workers will be even greater in the future than in the past. There are signs that the trade unions are entering upon a policy of preventing the undercutting of men by women rather by regulating women's wages than by excluding them entirely from the more skilled processes. The highly paid skilled workers as a class are not likely to be detrimentally affected by the augmentation of their numbers, whether the recruits come from one sex or both. It is the almost inexhaustible reserve of cheap unskilled or semi-skilled labour which is their real danger; the installation during the War of plant requiring only unskilled and semi-skilled labour, because no labour of a higher order is available, has only increased the difficulties.

3. An extension of the policy of equal pay for equal work, and, as a corollary, a minimum wage for unskilled labour both male and female This policy, which could be most effectively enforced by organised labour itself, should be so framed as to prevent the employment of unskilled labour from being more profitable than skilled in those forms of production in which they can be alternatively employed, *e.g.*, engineering. It may be desirable also to give further powers under the Trade Boards Act and to extend it to other trades.

4. A careful reconsideration of the 'half-time' system in those industries which still employ this form of child labour.

5. The withdrawal of widows with young children from the labour market by the institution of an adequate pension scheme, at the same time introducing further restrictions with regard to home work.

Statistics.

Appended are three tables. Tables I. and II. show the state of employment for industry as a whole at various dates from July to February compared with employment in July 1914. Table III. shows the state of employment for those industries most affecting women's labour. The tables are prepared from three Reports on the State of Employment in the United Kingdom issued by the Board of Trade,[13] which form the best available records of the economic effects of the War on employment. The first (Cd 7703) deals with the situation up to mid-October 1914; the second (Cd. 7755) states the facts for December; and the third (Cd. 7850) is based upon an inquiry in the middle of February 1915. There all information, as far as the public is concerned, stops short, though comprehensive inquiries are still taking place. In these official Reports little information is given with regard to non-industrial occupations such as railways, docks, shipping, the carrying trade, agriculture, clerks, and distributive trades; nor is information with reference to Government employment in Woolwich Arsenal or elsewhere, which has expanded considerably since the War, included. The October return covered 66 per cent. of the workpeople employed in large firms in industrial occupations and 10 per cent. of those in small firms. The December Report was based upon returns received from 23,000 industrial firms employing about 4,000,000 workpeople, or 43 per cent. of the industrial population, and the February return was even more comprehensive. The quality of the material thus provided is much superior to that upon which official unem-

[13] See article 'The Effect of the War on Industry,' by W. T Layton, in *Quarterly Review*, No 442. Three articles on 'The Influence of the War on Employment.' by H D. Henderson, in *Economic Journal*, December 1914 and March and June 1915, are also interesting contributions to the subject.

ployment returns are generally based, and it is to be regretted that no Reports have been published since last February, but it is to be hoped that later the full Reports will be made available to those who wish to have access to these invaluable records of the economic state of the country during the War.

TABLE I.

State of Employment at various dates since the Outbreak of War compared with State of Employment in July 1914.

(Numbers employed in July = 100.)

—	Males				Females			
	Sept. 1914	Oct. 1914	Dec. 1914	Feb. 1915	Sept. 1914	Oct. 1914	Dec. 1914	Feb. 1915
Normal time . . .	60·2	66·8	65·8	68·4	53·5	61·9	66·6	75·0
Overtime. . . .	3·6	5·2	12·8	13·8	2·1	5·9	10·8	10·9
Short time . . .	26·0	17·3	10·5	6·0	36·0	26·0	19·4	12·6
Total numbers employed	89·8	89·3	89·1	88·2	91·6	93·8	96·8	98·5
Contraction of employment	10·2	10·7	10·9	11·8	8·4	6·2	3·2	1·5
Known by employers to have joined the Forces	8·8	10·6	13·3	15·4	—	—	—	—
Net displacement (−) or replacement (+)[14]	−1·4	−0·1	+2·4	+3·6	−8·4	−6·2	−3·2	−1·5

It is interesting to check the results in Table I. with those obtained by Mr. Martin Holland in a unique return [15] from the whole of the Banks of England and Wales which throws considerable light on the movement of employment and wages during the first eight months of the war. Each bank computed the total of the cheques drawn for payment of wages in selected weeks. The following are the results :

Week ending	Total of Wage Cheques in England and Wales	The same expressed as percentages of the amount on July 27–Aug. 1, 1914
	£	
August 1, 1914	9,358,204	100
August 29, 1914	7,516,139	80·3
October 3, 1914	8,139,789	87·0
October 31, 1914	8,468,875	90·2
November 28, 1914	8,346,633	89·1
December 19, 1914	8,484,123	90·2
January 30, 1915	8,931,468	95·4
February 27, 1915	9,054,251	96·8
March 27, 1915	9,071,721	97·0

When allowance is made for the excess of short time in September and October and of overtime in December and February and for a slight rise in wages early in 1915, it is seen that the employment and the banking statistics are quite consistent with each other.

[14] A + (here and in Table II.) indicates the extent to which any industry has been compelled to draw in new employees.

[15] *Royal Statistical Journal*, July 1915.

TABLE II.

An idea of the dimensions of the changes which Table I. implies may be gathered from actual numbers. Applying these percentages to the approximate numbers occupied* (6,500,000 males and 2,500,000 females) in industrial occupations, according to the Census of 1911, we get the following approximate totals :—

—	Males				Females			
—	Sept.	Oct.	Dec	Feb.	Sept	Oct.	Dec.	Feb.
On full time . . .	3,913,000	4,342,000	4,277,000	4,446,000	1,337,500	1,547,500	1,665,000	1,875,000
Overtime	234,000	338,000	832,000	897,000	52,500	147,500	270,000	272,500
Short time	1,690,000	1,124,500	682,500	390,000	900,000	650,000	485,000	315,000
Total employed . . .	5,837,000	5,804,500	5,791,500	5,733,000	2,290,000	2,345,000	2,420,000	2.462,500
Contraction of numbers employed	663,000	695,500	708,500	767,000	210,000	155,000	80,000	37,500
Known by employers to have joined Forces	572,000	689,000	864,500	1,010,000	—	—	—	—
Net displacement (—) or replacement (+)	−91,000	−6,500	+156,000	+234,000	−210,000	−155,000	−80,000	−37,500

* Results based on these figures are only approximate. For on the one hand there has been a growth of population since 1911, but on the other among those whom the Census calls occupied there are a certain number at any moment unemployed.

TABLE III.

State of Employment in United Kingdom in Sept., Oct., Dec. 1914, *and Feb.* 1915, *compared with July* 1914, *in principal trade groups most affecting Female Labour.*

(Numbers employed in July 1914 = 100.)

Trade Groups.	Approximate Industrial Population. Census 1911.		Males.												Females.			
			Known by employers to have joined Forces.				Net Displacement (−) or Replacement(+)†.				Contraction or Expansion of numbers employed.				Contraction or Expansion of numbers employed.			
	Females	Males	Sept.	Oct.	Dec.	Feb.	Sept.	Oct.	Dec.	Feb.	Sept.	Oct.	Dec.	Feb.	Sept.	Oct.	Dec.	Feb.
Chemicals (including explosives)	29,000	122,000	10·8	12·2	15·4	17·4	+3·9	+6·0	+12·1	+18·6	−6·9	−6·2	−3·3	+1·2	−1·1	*	*	+38·0
Leather, Leather Goods, &c.	19,000	77,000	11·6	13·8	14·2	16·0	+4·1	+6·2	+10·3	+18·5	−7·5	−7·6	−1·0	+2·5	−11·8	+2·0	+10·1	+36·6
Engineering	21,000	665,000	10·0	12·2	14·6	16·1	−1·8	+0·2	+5·9	+7·0	−11·8	−12·0	−8·7	−9·1	−0·5	+2·2	+12·3	+26·4
Hosiery	52,000	18,000	6·7	6·7	7·5	12·3	+0·7	+5·6	+6·8	+9·6	−6·0	−1·1	−0·7	−2·7	+0·3	+5·2	+7·8	+10·4
Wool & Worsted	158,000	129,000	4·3	4·8	7·2	9·0	−3·2	+2·7	+7·9	+9·3	−7·5	−2·1	+0·7	+0·3	−4·3	−1·9	+3·1	+2·1
Boot and Shoe	49,000	199,000	6·7	6·7	9·9	10·9	−0·8	+0·5	+6·6	+9·8	−7·5	−6·2	−3·3	−1·1	−0·3	−1·7	−1·0	+1·3
Clothing	995,000	235,000	9·6	10·4	12·5	14·0	−4·1	−0·8	−1·6	+0·3	−13·7	−11·2	−14·1	−13·7	−8·6	−5·2	−3·2	−0·6
Cotton	400,000	259,000	4·3	7·0	9·6	11·6	−12·9	−10·3	−3·7	+0·5	−17·4	−17·1	−13·3	−11·1	−14·9	−14·0	−9·3	−3·0
Linen, Jute, Hemp & other Textiles	107,700	54,800	7·0	12·6	15·0	17·1	+2·4	+4·9	+6·8	+5·0	−4·6	−7·7	−8·2	−12·1	−1·0	−0·8	−1·4	−3·5
China, Pottery and Glass	34,000	83,000	9·9	11·2	13·3	15·5	−1·0	−0·3	+2·1	−0·8	−10·9	−11·5	−11·2	−16·3	−5·3	−4·8	−1·9	−5·6
Paper and Stationery	49,000	199,000	8·6	10·2	12·5	14·4	−0·9	−1·5	+0·3	+0·3	−9·5	−11·7	−12·2	−14·1	−4·4	−6·2	−6·0	−8·3
Food & Tobacco	100,000	276,000	9·2	10·8	13·4	16·1	+1·7	+6·7	+7·8	+7·5	−7·5	−4·4	−5·6	−8·6	−13·6	−11·8	−8·3	−9·6
Furniture	23,000	141,000	9·6	10·9	13·5	15·3	−9·5	−10·5	−6·8	−8·2	−19·1	−21·4	−20·3	−23·5	−13·1	−12·7	−8·4	−9·9
Cycle, Motors Wagon & Carriage Building	11,000	192 000	9·7	11·8	14·3	16·9	−4·8	−6·0	−3·2	−0·9	−14·5	−17·8	−17·5	−17·8	−8·5	−12·4	−5·1	−10·7

* No figures available.

† A + indicates the extent to which any industry had been compelled to draw in new employees.

TABLE IV.

The following table shows the number of males and females in England and Wales engaged in non-industrial occupations in 1911 :—

—	Women	Men
General or Local Government	50,975	248,624
National	31,538	140,814
Local	19,437	107,810
Professions	347,043	355,307
Clerical (Religious)	14,215	52,358
Legal	2,159	55,486
Medical	87,699	38,313
Teaching	187,283	76,428
Literary, Scientific, and Political	5,689	25,499
Art, Music, Drama, &c.	49,998	107,223
Domestic and Institutional Service	1,734.040	387,677
Domestic Indoor Service in Hotels, Lodging and Eating Houses	63,368	12,226
Other Domestic Indoor Servants	1,271,990	42,034
Domestic Outdoor Service	104	226,266
Other Service :		
Hospital, Institution, and Benevolent Society	41,639	17,394
Day Girls, Day Servants	24,001	—
Charwomen	126,061	—
Laundry Workers	167,052	12,464
Others	39,825	77,293
Commercial Occupations	126,847	663,316
Merchants, Agents, Accountants	4,301	164,450
Commercial or Business Clerks	117,057	360,478
Dealers in Money ; Insurance	5,489	138,388
Transport	24,474	1,399,394
On Railways	2,636	397,990
On Roads	2,821	471.994
On Seas, Rivers, and Canals	1,038	132,195
In Docks, Harbours, &c.	23	123,022
In Storage, Porterage, and Messages	17,956	274,193
Agriculture	94,722	1,140,515
Farmers, Graziers, Farm Workers	90,128	971,708
Gardeners	4,594	168,807
Totals	2,377,709	4,166,129
Without Specified Occupations or Unoccupied	10,026,379	2,208,535
Retired (not Army or Navy) Pensioners	87,894	422,213
Private Means	295,712	52,432
Others aged 10 years and upwards (including Scholars and Students)	9,642,773	1,733,890
Totals	12,404,088	6,374,664

Detailed Reports on Trades.

In the following Reports on separate trades no attempt is made to be exhaustive, since in any case that is not possible under present conditions, and the amount of information that we have been able to obtain differs considerably as between different trades. Some details are, however, given in each case of the position of each trade owing to the War, and the nature of the increased employment of women, especially with reference to those processes in which they have replaced or are likely to replace men.

The Report on the Metals and Engineering group was mainly drawn up from information received from the Birmingham district. The Leather and Tailoring Reports will be found interesting from the fact that they are trades into which women have been drawn in large numbers, but in which there does not appear to have been any considerable displacement of men by women. A Report on the Cotton trade is included mainly to show the effect of this trade upon the general figures for women's employment.

Reports on the possibilities of replacing men by women would not be complete without some mention of trades which, though depressed since the War, offer scope for the further employment of women. Accounts of the Printing and Pottery trades are therefore given. Reports on non-industrial occupations —distributive trades, clerical work in banks and other offices, railway work and transport, and Government employment, are also included. Owing to the complicated nature of the question it has been thought inadvisable in the few weeks at our disposal to attempt any inquiry into Agriculture, although this occupation offers a number of interesting examples of replacement.

Distributive Trades.

The retail distributive trades offer peculiar scope for the further employment of women, and since the War the increase of women's employment has been more general in these than in most other trades and occupations. In the majority of firms this increase would have been larger but for the fact that there has been a diminution of trade, especially in those shops dealing in better-class goods; shops catering for a lower grade of goods have been comparatively busy. The replacement of male by female labour in these trades is no new phenomenon, as is shown by the following table, but the shortage of male labour owing to the War has accelerated the process to a considerable degree.

At present the majority of employers consider their data and experience too inadequate to express final opinions as to the effects of the introduction or increase of women's labour.

Nature of Increase of Women's Work.

Since the War women have replaced men and youths as saleswomen in all those lines where it has been customary for women as well as men to be employed, *e.g.*, stationery, toilet requisites, and prepared drugs. They have also entered, both as saleswomen and as shopwalkers, and in isolated cases as buyers, into those branches which have in the past been regarded for the most part, and especially in larger shops, as men's monopoly, such as grocery, provisions, fruit and greengrocery, chintz, &c., heavy fabrics, men's hosiery, and hardware (light articles only). Women are now employed in practically every type of shop and warehouse except where the work is too heavy, *e.g.*, ironmongery and Manchester departments of drapery stores; or highly technical, *e.g.*, scientific instrument shops. Women have made their first appearance as commissionaires and timekeepers, as lift-girls, and in the packing departments in sorting, checking, packing, and putting up orders, as well as in the despatch departments. Some firms have appointed women on their administrative staffs, but rarely are women given positions of responsibility over men. Women are appearing for the first time on delivery vans, both horse and motor, as cycle-

The following table shows the increase per cent. of persons, male and female, employed in England and Wales in the chief distributive trades between the years 1901 and 1911 :

TABLE A.

Occupations	Census of 1901			Census of 1911			Increase or Decrease per cent.		
	Persons	Males	Females	Persons	Males	Females	Persons	Males	Females
Hat, Bonnet, Straw Plait, &c. .	5,751	3,815	1,936	11,116	4,417	6,699	+ 93·3	+ 15 8	+246·0
Clothiers, Outfitters . . .	22,107	17,701	4,406	36,642	27,045	9,597	+ 65 7	+ 52 8	+117·8
Boot, Shoe, Patten, Clog . .	21,886	14,223	7,663	33,466	22,114	11,352	+ 52·9	+ 55·5	+ 48·1
Drapers, Linen Drapers, Mercers	135,657	67,220	68,437	150,968	66,362	84,606	+ 11·3	— 1·3	+ 23·6
Milksellers, Dairymen . . .	40,901	35,338	5,563	56,971	46,700	10,271	+ 39 3	+ 32·2	+ 84·6
Cheesemongers, Buttermen, Provision Stores	20,882	16,510	4,372	24,567	18,448	6,119	+ 17·6	+ 11 7	+ 40·0
Butchers, Meat Salesmen . .	109,015	105,165	3,850	135,133	123,252	11,881	+ 24·0	+ 17·2	+208·6
Fishmongers, Poulterers, Game, &c.	32,267	28,746	3,521	44,684	36,999	7,685	+ 38·4	+ 28 7	+118·3
Corn, Flour, Seed Merchants .	16,457	15,486	971	20,168	17,946	2,222	+ 22·6	+ 15 9	+128·8
Bakers, Confectioners. . . .	72,197	30,402	41,795	109,933	43,691	66,242	+ 52·3	+ 43·7	+ 58·5
Grocers, Tea, Coffee, Chocolate Dealers	193,569	151,184	42,385	219,619	165,981	53,638	+ 13 5	+ 9·8	+ 26·5
Greengrocers, Fruiterers . .	52,627	40,700	11,927	72,289	51,813	20,476	+ 37·4	+ 27·3	+ 71·7
Others in Food	3,884	3,618	266	4,850	4,406	444	+ 24·9	+ 21·8	+ 66·9
Tobacconists	16,870	10,200	6,670	21,298	11,702	9,596	+ 26·2	+ 14·7	+ 43·9
Multiple Shop, Multiple Store Proprietors, Workers (General or Undefined), General or Unclassified Shopkeepers, General Dealers	51,576	23,539	28,037	90,077	41,819	48,258	+ 74·6	+ 77·7	+ 72·1
Dealers in Precious Metals, Jewellery and Watches	4,763	3,855	908	14,906	12,077	2,829	+212·9	+213·3	+211·6
Dealers in Instruments, Toys, &c.	4,724	2,881	1,843	7,672	5,115	2,557	+ 62·4	+ 77·5	+ 38·7
Stationers, Law Stationers, other Dealers in Paper	22,335	12,652	9,683	26,695	13,989	12,706	+ 19·5	+ 10·5	+ 31·2
Book, Print Publishers, Sellers .	14,788	12,235	2,553	16,864	13,498	3,366	+ 14·0	+ 10·3	+ 31·8
Chemists and Druggists . .	28,448	25,343	3,105	32,241	26,851	5,390	+ 13·3	+ 6·0	+ 73·6

carriers, and as milk-vendors. Girls and young women have been employed in hundreds in place of boys for newspaper delivery and at railway bookstalls. In those branches of these trades in which the work is rough, such as dairy work and heavy van driving, the extra women who have been drawn in since the War have come from factories, domestic service, laundries, and other occupations where the work is heavy or unpopular or wages comparatively low. For the lighter work the women who have come in have either been in business before, generally in occupations in which there has been a contraction in employment owing to the War, *e.g.*, dressmakers and milliners and light luxury trades generally; or are women from comparatively well-to-do families hit by the War; or girls of fifteen to eighteen years of age mostly from secondary schools. In comparatively few cases are married women quoted as returning.

Various estimates ranging from 50 to 100 per cent. are given as to the amount of increase of women's labour in these trades. The Trade Unions concerned anticipate a continued increase in women's employment, and point to the grocery trade, where already the numbers have doubled. It has been found impossible to obtain sufficient information in statistical form to be able to quote figures.

Amongst a number of employers there is still a considerable reluctance to engage women on work previously done by men. Some of them prefer to run their businesses with insufficient staff rather than take on women. The reasons stated for this reluctance are :

(*a*) Women are untrained. The male employees lost were to a large extent skilled men, and their places cannot be taken by men or women without the necessary technical experience. This was stated to be the case by certain firms dealing in jewellery, ironmongery, furniture, books, and drugs. The normal recruiting to the trade in the case of male labour is by boys and youths who are promoted as they prove efficient.

(*b*) It is not worth training women as many of them are not likely to remain in the trade. It is stated that the possibility of marriage causes her attitude to her work to be less stable than that of men. Uncertainty as to the duration of the War also influences employers in this respect.

(*c*) The work is too heavy or dirty, *e.g.*, in furniture and piano shops and the meat and fishmongery departments of general stores. In the heavy departments of drapery firms employers are apportioning the heavier work to the men and the lighter to the women. A firm employing women in its despatch and packing departments has arranged that men only shall transfer cases to the warehouse. Some dairies with many branches have had to reduce the number of calls for women on milk rounds, giving a few extra to each man. A firm employing women at the fish and meat counters does not ask them to prepare and clean the fish.

(*d*) As staying power is essential even when actual physical strength is not, women are not found capable of so large an output as men. This was the view expressed by 85 per cent. of the employers visited, some quoting comparative figures. Thus, a large provision merchant uses three women for two men's work, a dairy has had to put in two women where one man sufficed, and has had to reduce the number of calls in the women's rounds; a general store and a hardware firm put the value of a trained woman at 75 per cent. of that of a man. Many employers allow that output is, to a large extent, a matter of training and practice, but in spite of this they consider women of less efficiency than men when tested by output or staying power, the cause being partly physical and partly psychological. Men generally enter these trades as boys, and the trades are 'picked up.' Definite schemes of training are almost non-existent save in very large stores, where lectures are sometimes given. The London County Council Higher Education Committee has started a scheme for training women in the grocery trade, but it is premature to attempt an analysis of the results. Employers prefer 'experience' to 'lectures.' Men acquire experience and knowledge over a period of years, and it is obvious that adult men or women from other trades find it extremely difficult to compete with, or to do the work of, those having years' experience of the trade. Men enter the grocery trade as boys of fourteen, in

circulating libraries they enter at the same age, and 'it takes years to produce a good salesman of fabrics.' Obviously adult women are heavily handicapped under such conditions.

(*e*) Though painstaking, women do not possess initiative in the same degree as men, and often they lack interest in their work. A few employers absolutely deny this.

In spite of these objections women have for some years past been entering these trades in increased numbers, as shown in Table A, and while a majority of employers maintain reasoned objections to women's employment, such as physical disabilities and the probability of their withdrawal from the trade on marriage, a minority are no doubt largely influenced by the custom of the trade in regard to their employment. When asked 'If you could get men would you employ them in preference to the extra women that you have taken on?' 50 per cent. of employers stated 'No'; 28 per cent. said 'Yes,' and 22 per cent. were doubtful. Patriotic as well as economic motives, however, largely influenced these replies. Employers are generally very cautious in taking on women for new work, and in few cases, so far as could be discovered, had experiments proved failures. Trade Union opinion agrees that women's efficiency is lessened by (1) physical strength, (2) marriage, though obviously the former depends very much upon the kind of work done.

One particular job in a shop generally consists of several processes, some light and some heavy, some skilled and some less skilled. Obviously there is difficulty in introducing untrained men or women into such a system unless reorganisation and subdivision of work is effected. This apparently has been very rarely done.

From the report of one large firm, where great and marked success and enterprise renders the opinion of its manager valuable, it appears that such reorganisation and subdivision of labour is advantageous. He says that, thanks to careful subdivision prior to the War, he has not found it necessary to put in more women to do the work of men; that the majority of the women with some experience are capable of the same work, and can, therefore, earn the same pay. For example, the women commissionaires and lift attendants were not expected to put up shutters and scrub out lifts; the delivery men had no cleaning or repairing of their vans to do; and in the provision department the salesmen whom the women replaced were doing no heavier work than a woman is capable of doing. A considerable subdivision of work is, however, less possible in small shops than in large stores One employer, who was typical of many, when questioned on this point, replied that 'Such subdivision is more arduous than manipulating the pieces at a game of chess.' The reluctance of some employers to reorganise their business on these methods has made the task of taking on women and releasing men more difficult.

Wages.

The question of wages is a difficult one. Only in very exceptional cases can piece-rates be paid. Throughout these trades time-rates are the rule, though commissions are often earned in addition to fixed wages. It is obvious from all reports that, with very few exceptions, women's wages are less than the wages of men. This is due to:—

(*a*) A difference in the work done by men and women. Very few women are said to be doing exactly the same work as that previously done by the men replaced.

(*b*) The smaller output of the women who have replaced men and the probable lack of continuity of their work.

(*c*) Social and personal factors. Women ask and are paid less wages. Custom also plays a considerable part.

As women are for the most part untrained and are often doing the work of boys and youths and rarely the full work of men it is difficult to prepare any comparative table of wages. One can only give a few examples.

One chemist employing dispensers states that they get the same, or even more if they are more skilled. The question is entirely one of skill.

A firm employing women instead of boys and youths as messengers and lift attendants pays them 10*s.* to 15*s.*, where youths, after some experience, got 12*s.* 6*d.* to 18*s.* and two meals.

A jeweller employing casual labour to clean silver paid a woman 15*s.* where a man would have got 30*s.*, though she was acknowledged to be as good.

A dairy is paying women on milk rounds 19*s.* 9*d.* where men got 25*s.* The number of calls is, however, reduced. Another dairy is paying a woman 16*s.* a week for washing cans where a man got 26*s.* In this case, however, two women are employed to do the work of one man. In the majority of cases three women seem to do the work of two men.

In the grocery trade three-quarters of the men's wages is felt to be as much as can be asked for by a section of those interested in the question of women's wages.

Many of the wages at present fixed are to a large extent experimental, and they differ very much between different firms and districts. The Trade Union concerned, though in theory in favour of equal pay for equal work, does not endeavour to secure equal pay. It tries to secure three-quarters of the men's pay for women everywhere except in London, where the demand is four-fifths. It is stated that the best shops pay men more than the minimum demanded, while few pay the women as much. In the second grade shops men are, for the most part, paid the minimum, but very few women attain it. Still a large number of shops do not pay to women one-third of the minimum demanded for them by the Union. The majority of employers state that untrained women's labour is not cheap labour and that women require more supervision than men. Since the War their wages bills for the same output have been heavier than before. One provision firm, having many branches throughout London and the country, stated that the value of male labour over female is approximately 30 per cent. on the same wages. Some firms stated that the difference in the wages of trained men and women is greater than is the difference in their efficiency. They generally referred to social custom as explaining this discrepancy. For the most part women shop assistants are unorganised, though a considerable number have joined a union since the War.

33·3 per cent. of employers expressed a belief in equal pay for equal work, 27·7 per cent. stating that they were paying it. As the character of most of the work prevents the fixing of piece-rates the employers' opinion alone can fix the question of equal work. One states he pays 'according to the man's or woman's capacity,' another that he believes in equal pay 'where the women do the same work and the same amount without supervision.'

Of those who do not believe in equal pay for equal work 50 per cent. say women ask for less and get less, and 50 per cent. that 'being women' or 'only having themselves to support' they get less.

All employers visited say they are ready to take back their men when and if they return. They do not, however, expect this problem to be a serious one. Youths in many cases are now doing the work previously done by men, and women have taken the boys' places. Where women have taken the place of boys and youths, *e.g.*, on lifts, they are likely to remain. The opinion is often expressed that many of the men who return will not wish to return to a sedentary life. One large drapery firm instanced that after the South African War only 6 per cent. of their men wished to return. Many employers think that women will not wish to remain at rough, out-door work such as milk-delivery and van-driving, especially during the winter months. Many of the women themselves, and especially those from better class families, regard their entry into the trade as a temporary one, though, on the other hand, women from occupations such as domestic service and factory workers intend if possible to remain. Many of the women introduced are young and are now learning the trade and are not likely to wish to leave it. The majority of employers seem, even reluctantly, to have accepted the fact of the further entry of women into these trades and they are now experimenting and testing. They are unwilling yet to give final opinions, and the above inadequate statement of the problem reflects generally the views of the trade.

It is difficult to draw definite conclusions from information which cannot fully be produced in statistical form, but the following general remarks are suggested by the foregoing evidence :

(1) The replacement of men by women has occurred to a larger extent in the distributive trades, and especially in grocery, than in most other trades and occupations. Practically the only limitations to women's employability in these trades have been in work requiring physical strength or technical knowledge.

(2) The movement of labour into these trades has been from trades which are depressed owing to the War, such as millinery, dressmaking, and luxury trades generally. Girls from fifteen to eighteen years of age, mostly from secondary schools and women from comparatively well-to-do families hit by the War, have also been absorbed to a considerable extent. The movement into the heavier branches of the trades has been largely from lower-paid or less attractive occupations, such as some kind of factory-work, domestic service, and laundry-work. In few cases have married women returned.

(3) In the opinion of the majority of employers, the actual value of a woman as a worker is about 30 per cent. below that of an average man employed in the same capacity, the difference being due partly to physical strength and partly to incapacity of continued employment because of marriage.

(4) A minority of employers, however, find that, with improved organisation and greater subdivision of processes, many places can be found for women in which their economic value is equal to that of an average man.

(5) The actual wages of women tend to be lower in proportion to those of men employed in similar capacities than would be justified even by a less favourable estimate of their economic value. This discrepancy appears to be due to custom and to the inferior economic status of women as workers.

Railways.

1901 Board of Trade Returns—Total (Men and Women) = 575,834
1913 „ „ „ Total „ „ = 643,135
= + 11·6 increase per cent.
1901 Census : Women, 1,411. 1911 Census : Women = 2,636 = 82·9 increase per cent.

Prefatory Note.

[Since this Report was written an agreement has been reached between the railway companies of Great Britain and the National Union of Railwaymen, to take effect as from August 16, 1915, in regard to the rates of wages paid to women. This agreement is as follows :

'An assurance was asked for and given that the employment of women in capacities in which they had not formerly been employed was an emergency provision arising out of the circumstances created by the War and would not prejudice in any way any undertaking given by the companies as to the employment of men who had joined the colours on the conclusion of the War.'

'It was agreed that the employment of women during the War in capacities in which they had not been previously employed is an emergency arising entirely out of the War and is without prejudice to the general question of the employment of women.'

'The pay of women employed in grades in which they were not employed prior to August 1914 shall, for the duration of the War, be the minimum pay of the grade.'

Its application, therefore, is to women employees on the operative staff only (and not the clerical staff) and includes :

Ticket collectors and examiners, messengers, halt and platform attendants, office porters, pneumatic tube attendants, checkers, shippers, weighbridge clerks, time-keepers and carriage cleaners.

In respect of carriage cleaners, as in the case of one or two other occupations, *e.g.*, ticket collectors and halt attendants, women were employed in these capacities in small numbers and on certain railways prior to the War, but their employment was so far exceptional that for the purposes of this agreement it was decided to regard them as occupations new to women. It follows from this arrangement that women are henceforth liable to the same hours of work as the men and the same conditions of service, so that if, for instance, it seems convenient and desirable to put women carriage cleaners on the outside work, there is no technical reason which can be urged against their being so employed.

Many of the remarks made in this Report on the question of women's wages and hours of work are consequently rendered inapplicable at the present moment. It has not, however, been thought desirable to exclude or modify these remarks, and for this reason. The agreement with regard to women's rates, just as the employment of women in capacities new to them, is clearly understood to be an emergency provision, arising out of the circumstances of the War, and forms no precedent whatever. This understanding applies equally to their hours of work.

The position, therefore, is this: if women prove themselves capable of performing equal service with men under equal conditions of work, then the case against their employment on the railways falls to the ground and they cannot be excluded. Further, instead of remaining content with the present agreement to pay the minimum rate of the grade occupied, they will be justified in demanding the increases customary in the men's scale. If, on the other hand—and this seems to be the more likely event—they prove unequal to the demands made on their physical powers and general ability to cope with the work, then the question of their partial employment, with shorter hours and lighter work, may come up for reconsideration. In the former case no argument is possible, but in the latter there are advantages and disadvantages to be weighed, and it is because some attempt has been made to review these that this Report is left in its present form. The experiment that is now to be tried of giving women equal work and equal wages is one of great interest. It remains for experience to throw light upon various important questions, as, for instance, whether the wages bill will increase, whether women possess unsuspected abilities for this kind of work and justify the consideration of their permanent employment in the new posts. But, it is necessary to repeat, if it should happen that women do not realise the highest expectations, that will not in itself justify the total exclusion of them from these branches of the service. If we should be faced with a shortage of men after the War, a subdivision of labour, by which women do some of the easier work, with shorter hours and lighter responsibilities, may well prove to be a desirable and necessary step. And in that case it seems worth while to state the conclusions reached in this Report with regard to wages and hours, even though not applicable in the present conditions, because at first sight the apparent injustice of a lower scale of pay for women is likely to be misleading, unless the actual character and value of the services which women can perform in these new branches are carefully weighed.

For these reasons the Report is left in its present form, with the understanding that the new agreement temporarily suspends the conditions as to wages and hours here represented, and with the hope that the agreement, when put into practice, will shed some light on the always difficult question, how far women are capable of giving service of precisely equal value with men.]

Outdoor Staff.

It seems to be not generally understood that the increase in the employment of women on the railways has arisen entirely out of the emergency created by the War. The companies have encouraged enlistment among their employees, provided due notice of their intention is given, and in consequence a steady flow of recruits has been maintained, the total enlisted from the railways up to the present time being estimated at 89,000 to 90,000, or about 14 per cent., at which point it is thought the margin of possibility has nearly been reached. Enlistment among those engaged in the manipulation of traffic, though less than in other branches, has been sufficient to demand the introduction of women into

new branches. The demand up till now has varied considerably with the different railways; in one company 263 extra women have been taken on, in another 170, but in others much smaller numbers.

The grades chiefly affected are those of carriage cleaners, ticket collectors, and checkers. On December 31, 1913, there were 305,000 men engaged in the manipulation of traffic, of whom carriage cleaners=6,531; ticket collectors=3,741. The number of women on the railways is returned in the 1911 census as 2,636, of whom 1,120 were clerks, &c., and 1,156 were 'other railway servants.' Women are also being employed experimentally in smaller numbers as messengers, weighbridge clerks, time keepers, invoice checkers, office porters, and halt attendants, and by one company at least as dining car attendants. The increased employment of women in the offices is considered separately. The employment of women as carriage cleaners dates from some two years back, but though their work as such compares very favourably with that of men in quality, it appears still to be an open question whether this will be a permanent occupation for women. Hitherto they have worked an 8-hour day, against the men's day of 10 hours. The quality of their work is in some respects superior to that of men, but in quantity it is relatively less. Some companies state that they have to employ a proportion of 3 women to 2 men, or of 6 to 5, to get the same amount of work. Piecework records show that women will generally earn 10 per cent. less than men on the same work. There are the further objections that women are not so well fitted to do the outside, but only the inside cleaning; that it is generally necessary to have platform or siding accommodation for the cleaning of carriages, as it is regarded as undesirable and dangerous to have women cleaning carriages on the permanent way. Nevertheless the War has given a considerable impulse to the employment of women as carriage cleaners—one company has taken on 140 additional women, which is one-sixth of their total of male carriage cleaners employed before the War, and they are likely to continue this occupation for some time to come. The effect of the new agreement in regard to hours, introducing a 60-hour week for women (as compared with 47 hours in 1913, increased more recently to 48), must remain as yet uncertain, but it is likely that, though their work may continue to be satisfactory, the women themselves may at the end of the War demand a return to the *status quo*.

The introduction of women ticket collectors and checkers, on the other hand, is almost entirely a new departure, their total in the census of 1911 being returned as 19. Now one company alone has 78, which is just under one-sixth of the total of men so employed before the War. Three companies had recently a total of 169 women ticket collectors. One fact which has facilitated the introduction of women with little or no previous training, is the suspension of cheap bookings and excursion tickets, simplifying the work as compared with a normal summer season to a very appreciable extent.

It is still early to form a judgment as to the suitability of ticket collecting as a permanent occupation for women, and it is made more difficult by the fact that existing conditions are not normal. Thus doubt is generally expressed whether in normal times an equal number of women ticket collectors would be sufficient to cope with the work formerly done by men. One Railway Company at least, it is true, has followed the policy of substituting one woman for each man gone, and finds the work is satisfactorily performed—women working one hour less at main stations. Another Company, on the other hand, substituted 3 shifts of women for 2 of men, and proposed to continue this arrangement for the present. Prior to the new agreement, women were working shorter hours than men at main stations—at Paddington, for instance, they worked 1 hour per day less—and it remains to be proved whether, as a permanent arrangement, 3 shifts of women would not be necessary, or at least desirable, to do the work of 2 shifts of men. In the first instance they were not employed, generally speaking, before 7 A.M. or after 9 P.M., whereas men are liable to duty between the hours of 5 A.M. and 1 A.M., but it was soon recognised as improbable, if not impossible, that this distinction could be permanently maintained. Even when the system of 3 shifts of women for 2 shifts of men is accepted, it still remains doubtful whether equal efficiency is obtained, and it is clear that, apart from the demand for men for war service, the companies are not yet converted to

any change of policy and, for the present at any rate, would generally prefer men ticket collectors to women.

The chief objections to the employment of women ticket collectors are :

1. The limitations to their sphere of activity.
2. Their comparative inability to deal with extra or sudden pressure or with the rougher classes of passenger traffic.

These two disabilities, in combination, constitute a serious obstacle; thus at main stations and junctions, while specialisation and subdivison of functions render the first objection inoperative, the second objection is strongly accentuated. At provincial stations the position reverses itself and it is the first objection which is operative, while the latter is absent. The provincial ticket collector often discharges a variety of duties involving considerable training, endurance and initiative, so that the introduction of women is regarded as undesirable except where the sphere of activity is limited to the issuing and collecting of tickets, and such other light duties as checking, invoicing, and the telegraph.

There are further obstacles in the isolation of outlying offices, which could not be put in the sole charge of women, as they are in the case of men, and in the mobile character of the work, which frequently involves the transferring of workers in the lower grades from one district to another. It is generally admitted that even if it were desirable on other grounds, women show themselves less adaptable than men to such change of surroundings and of routine.

Finally the shorter hours, and the exemption of women from early and late turns, which the subdivision of work makes possible in the case of main stations, are obviously impossible in the case of small provincial stations where a single booking clerk is employed.

Within limits, therefore, the employment of women as ticket collectors both in main and provincial stations appears to be practicable, but it is not capable of indefinite extension and is further complicated by the question of early training, which would have to be much more seriously considered if the employment of women were regarded in the light of a permanent change instead of, as now, a purely emergency measure. Because it is an emergency measure and because of the abnormal condition of traffic, the unusual procedure of introducing women without training can be justified. Normally, the ticket collectors are recruited from the porters, and the direct introduction of men or youths from outside the railway service for such duties is a quite exceptional occurrence, though one Railway Company apparently follows this method and recruits only a very small percentage of its ticket collectors from among its porters. In consequence a newly appointed collector has, as a general rule, three or four years' varied experience behind him, which has a considerable practical application to his new routine. But in view of the strong expression of opinion against the permanent employment of women as porters, it is difficult to see how women can receive any such practical training for the duties of ticket collecting. In any case the balance of advantage must always rest with the men, because it would be unsuitable for women to enter the railway service on the operative side (as contrasted with the clerical) at as early an age as men.

Of the men's attitude towards the question different accounts are given. The position of the ticket collector is a popular one, being regarded on the one hand as a 'soft' job and on the other as the stepping stone to the position of guard, inspector, and other responsible posts. Therefore in the case of the more unambitious and conservative men, their attitude is not unlikely to be, and in some instances is reported to have been unfavourable. The entry of women, as one railwayman expressed it, is 'forcing' the men to accept promotion. It is natural to find this opinion reversed in the case of the more ambitious men, because the employment of women in the less responsible posts and without any expectation or desire of promotion, must tend to accelerate the promotion of the men. The Railwaymen's Union has opposed this division of the work into skilled and unskilled labour, but as far as the employment of women is concerned it is difficult to see how this can be otherwise, in view of the special disabilities of women, the difficulty of training them

for posts of responsibility, and the comparatively shortness of their careers in the service.

A second objection raised by the men is that women monopolise the middle or favourite turns, and the more mechanical part of the work, while the rougher, harder, and more responsible duties, with the late evening and early morning turns, are laid on the shoulders of the men. This objection is not universally applicable, however, even now, and in any case it is admitted that this distinction could not be permanently maintained, and it is probable that ultimately the arrangement would be to employ women during the working hours of 5 A.M.—1 A.M. in three shifts.

Against the view, freely expressed, in some quarters, that the entry of women to this branch is a menace to the men's position, this much may be said, that from the employer's point of view, it is a vital interest that they should maintain the efficiency of the men ticket collectors, as being a considerable recruiting ground for the higher branches of the service, and that the employment of women in the more mechanical duties of the service can only have the effect of equipping the men all the better for higher responsibilities. This need of a permanent source of supply of efficient men renders unlikely any attempt to lower the standard.

In conclusion it may be mentioned that the great flood of applications received by the Railway Companies proves the great attraction which this new occupation possesses for girls. A large number, but not all, are daughters or relatives of Companies' servants; others are stated to have come from restaurant work and other depressed occupations.

Of the minor experiments, that of the dining car service is the most important. The G.W.R. is already employing women in this branch, and no reason is found against extending their employment to cover the whole service. On the other hand, an unsuccessful experiment is reported from one of the Northern railways, whose experience on a trial trip was that women lacked the nerve for carrying dishes on a moving train. In regard to women platform porters the experiment is being tried, but not on a large or systematic scale, and their permanent employment is unlikely; the objections which are raised in regard to other branches apply with increased force to this service. Porters have in some instances been recruited from among the women carriage cleaners.

Clerical Staff.

A considerable extension in the employment of women has occurred in recent years, and the results have surpassed expectations. As telegraph clerks and telephonists they have been employed for years with satisfactory results. As correspondence clerks their claims have been long established. A more recent step has been the employment of women in goods and parcels offices, in the work of invoicing and checking, and in particular as booking clerks. The establishment of a training school by the L. B. & S. C. R., where girls of 15-16 are given 3 to 4 months' training in these duties, is evidence of the considerable impulse given to the employment of women in these branches since the war.

Conditions in the railway service are said by Trade Unionists to have become increasingly favourable to the employment of women in recent years, since the reduced competition between different systems has the effect of making the standard of efficiency required from the railway clerk less exacting. The objections to their employment in certain branches, the goods department, parcels office, weigh office, invoicing, checking, &c., are substantially the same as in the case of ticket collectors and in some instances apply with greater force :—

(1) Limitations to women's sphere of activity.
(2) Isolation of railway clerks in outlying offices.
(3) Mobile character of the work, frequently involving transference from one district to another.
(4) The difficulty of a practical early training.
(5) Women have the easier work, while men take the night work and late evening and early morning turns.

In regard to the limited sphere of women's activity, a point of special import-

ance is the variety of functions demanded from clerks, more particularly in smaller stations. They issue tickets, despatch luggage and parcels, manage the telegraph, make inquiries for missing or injured packages, and, most important of all, discharge certain directive functions in giving orders in the case of trains delayed, which involve visits to the signal box, goods shed or shunting yard. Their position being in many instances almost the equivalent of under station master, it is obvious that women are handicapped by their shorter and less thorough experience.

In the case of booking clerks, the great increase in the employment of women since the War has been greatly facilitated by the suspension of cheap bookings and excursion tickets and the consequent simplification of the work. It is generally believed that in a normal season and in a large station, where the system of classifying tickets is very complicated, women would be unequal to the strain and difficulty of the work. In small provincial stations the variety of functions discharged is an obstacle to their employment as booking clerks; consequently the permanent employment of women in this capacity is limited to the easier posts in large stations and wherever specialisation and subdivision are such that the booking clerk's work is, in fact, restricted to booking.

Wages.

It is a very difficult matter to compare rates of pay received by men and women in the railway service. Where it is a clear case of equal work, as in the case of carriage cleaners, the principle of equal pay has come to be generally accepted by the Companies. The wage paid to carriage cleaners in one Company employing 140 women has taken the following course:

—	Men			Women		
	Wage	Hours	Hourly Rate	Wage	Hours	Hourly Rate
	s		*d.*	*s.*		*d.*
1913 . .	21	60	4·2	15	47	3·98
1915 . .	21	60	4·2	16	48	4·0

War Bonus granted . . . Men 3*s*. Women 2*s*.

Piece rate records show that women will generally earn 10 per cent. less than men on the same work, but having regard to the shorter hours worked by women and the good quality of their work in this service, it seems probable that their net efficiency is little if any less than that of men. Another Company pays its women carriage cleaners 18*s*. a week, where men formerly received 1*l*. See appended Table of particular instances of comparative rates paid to men and women:

Carriage Cleaning.

Men	Women
(1) 30*s*. compared to	21*s*
(2) 21*s*. for 47 hour week plus piece-rates, yielding in total up to about 32*s*. for a 60-hour week	16*s*. plus War Bonus of 2*s*. for the normal 47-hour week, no overtime allowed.
(3) 21*s*. 6*d*. plus War Bonus 3*s*. = 24*s*. 6*d*.	18*s*. plus War Bonus 2*s*. = 20*s*.
(4) 20*s*. 6*d*. plus War Bonus 3*s*. = 23*s*. 6*d*. for 1st six months. By agreement 21*s*. 6*d*. and War Bonus for 2nd six months = 24*s*. 6*d*.	18*s*. plus War Bonus 2*s*. = 20*s*. for 60-hour week.
(5) 18*s*. for 10-hour day plus overtime (at rate of time and a quarter) plus night work.	16*s*. per 9-hour day with no night work and less hours on Sunday. No overtime.

1915. August 23.—Agreement reached in all Companies that for the duration of the War women cleaners should receive the same wage as men and work the same hours. [*Prefatory Note.*]

Traffic Department.

The basis generally adopted in the case of women ticket collectors has been to pay them 3*s*. a week less than the scheduled rate for the position. Thus on one system women are receiving 24*s*. instead of the men's rate of 27*s*.; on another, 20*s*. instead of 23*s*. Seeing that women are appointed direct to the post without previous training, whereas men graduate from lower grades, this was regarded as a fair and liberal arrangement, and the experience has been that women are only too ready to come in on these terms.

From what has already been said on the subdivision of labour among women and men ticket collectors, it is clear that the value of women's work is less than that of men and that this difference in the rate of wage no more than expresses the superior training of the men, and the more arduous, difficult, and responsible nature of the men collectors' work.

The danger of undercutting, which is being urged in some quarters, does not appear to be very serious in view of the importance to the Companies, fully recognised, of the efficiency of the men ticket collectors, as being the chief source of supply for the more responsible posts of the service, in consequence of which any attempt to level down this branch of service to the plane of semi-skilled or lower grade labour would be suicidal.

Ticket Collecting.

	Men	Women
(1)	23*s*.	20*s*.
(2)	27*s*.	24*s*.
(3)	23*s*.	18*s*. plus 2*s*. War Bonus
(4)	25*s*. minimum } plus War Bonus 3*s*. 28*s*. maximum }	22*s*. no Bonus
(5)	23*s*. plus War Bonus 3*s*.	20*s*. plus 2*s*. War Bonus
(6)	25*s*. plus War Bonus 3*s*.	20*s*.

The fact that a woman will remain a comparatively short time in the service makes the woman a bad investment to the employer, in compensation for which he keeps her rate of pay, generally speaking, practically unchanged during the last five or six years of service; the woman, on the other hand, is sometimes compensated for the lack of prospects and less training than men, by a relatively higher wage in the earlier stages of her career. In some instances (see appended tables) she is paid actually a higher wage between the ages of 16-19 than the youth of corresponding age on the same work. With a man the position is reversed, since in the earlier stages he accepts a relatively low rate of wage, regarding the remuneration of his services as being in part paid in training (which in itself implies prospects) and part, as it were, held in trust, to be paid in after years by a series of promotions and a rate of pay relatively much higher.

With these considerations in view, that a woman's inferior training and prospects handicap her somewhat unfairly in competing with men on the operative side of the railway staff, there seems to be good ground for pressing the extension of the policy of paying women a proportionately higher rate during the early years of service. As regards the future of the railway clerk, the unions view it with some misgiving; the increased employment of women on the clerical side of the service is, in fact, much more likely to be permanent than on the operative side, and in certain branches it may be even further extended. Decreasing competition between the different systems during recent years, it is argued, must end in lowering the standard of efficiency demanded from railway clerks and is likely to lead to a further increase in the employment of women, and this, it is feared, will have a depressing effect upon the men's wages. The disabilities of women as compared with men in several branches of the clerical service, and the fact that the harder and less pleasant work and the early and late turns must continue to be performed by men, constitute a strong argument in the men's favour, and the right policy seems to be to insist on the higher value of the men's service and to demand the maintenance of their present rates of pay, rather than to demand what is less justified by the facts, the raising of women's rates to an equality with those paid to men.

Scales of Pay for Women Clerks in Railway Offices.

Railway A.

Age	Women's Rates per week	Men's Rates per week	Difference per week
	s. d.	*s. d.*	*s. d.*
16	6 11	11 6	4 7
17	9 2	15 4	6 2
18	11 6	19 2	7 8
19	13 10	23 0	9 2
20	16 1	24 11	8 10
21	18 5	26 10	8 5
22	20 9	28 9	8 0
23	23 0	30 8	7 8
24	25 4	32 7	7 3
25	25 4	34 6	9 2
26	25 4	36 5	11 1
27	25 4	38 4	13 0

Railway B.

Age	Women's Rates per week	Men's Rates per week	Difference per week
	s. d.	*s. d.*	*s. d.*
15	5 0		
16	10 0	10 0	
17	12 0	12 0	
18	14 0	14 0	
19	17 0	17 0	
20	20 0	20 0	
21	20 0	22 0	2 0
22	20 0	24 0	4 0
24	20 0	26 0	6 0
25	20 0	28 0	8 0
26	20 0	30 0	10 0

Railway C.

Age	Women's Rates per week		Men's Rates per week, Col. 3	Differences	
	Managerial Staff, Col. 1	Others, Col. 2		Cols. 1 and 3	Cols. 2 and 3
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*
16	12 0	10 0	11 6	6*	1 6
17	14 0	12 0	15 4	1 4	3 4
18	16 0	14 0	19 2	3 2	5 2
19	18 0	16 0	23 0	5 0	7 0
20	20 0	18 0	26 10	6 10	8 10
21	22 0	20 0	30 8	8 8	10 8
22	24 0	20 0	30 8	6 8	10 8
23	26 0	20 0	34 6	8 6	14 6
24	28 0	20 0	34 6	6 6	14 6
25	30 0	20 0	38 4	8 4	18 4

* Increase.

NOTE.—The scale for men quoted above is that applicable to London. For the Provinces it does not go beyond 30*s.* 8*d.*, and in calculating for Provincial Towns this must be adjusted.

Railway D.

Age	London Stations			Provincial Stations		
	Women's Rates	Men's Rates	Difference	Women's Rates	Men's Rates	Difference
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
16	10 0	11 6	1 6	10 0	11 6	1 6
17	12 0	13 5	1 5	12 0	13 5	1 5
18	14 0	15 4	1 4	14 0	15 4	1 4
19	16 0	17 3	1 3	16 0	17 3	1 3
20	18 0	19 2	1 2	18 0	19 2	1 2
21	20 0	23 0	3 0	20 0	23 0	3 0
22	22 0	26 10	4 10	22 0	24 11	2 11
23	24 0	28 9	4 9	24 0	26 10	2 10
24	26 0	30 8	4 8	26 0	28 9	2 9
25	28 0	32 7	4 7	26 0	30 8	4 8
26	28 0	34 6	6 6	26 0	32 7	8 7
27	28 0	36 6	8 6	26 0	34 6	6 6
28	28 0	38 4	10 4	26 0	34 6	8 6
29	28 0	42 2	14 2	26 0	34 6	8 6

The Provincial Rates for men quoted above are for small stations, so that the difference will be for small stations only. The rate at large stations for men is the same as in London, except that it stops short at 38*s.* 4*d.* To find the difference at large Provincial Stations add after age 23, 2*s.* to the London difference, and at the age 29, 5*s.* 10*d.*

Railway E.

Age	London Stations			Provincial Stations		
	Women's Rates	Men's Rates	Difference	Women's Rates	Men's Rates	Difference
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
16	10 0	10 0	—	10 0	8 0	2 0*
17	13 0	13 0	—	13 0	11 0	3 0*
18	16 0	16 0	—	16 0	14 0	2 0*
19	18 0	19 0	1 0	18 0	17 0	1 0*
20	20 0	22 0	2 0	20 0	20 0	—
21	22 0	25 0	3 0	22 0	23 0	1 0
22	22 0	28 0	6 0	22 0	26 0	4 0
23	22 0	30 0	8 0	22 0	28 0	6 0
24	22 0	30 0	8 0	22 0	28 0	6 0
25 & 26	22 0	32 0	10 0	22 0	30 0	8 0
27 & 28	22 0	34 6	12 6	22 0	32 0	10 0
29 & 30	22 0	36 5	13 5	22 0	34 6	12 6
31	22 0	38 4	16 4	22 0	34 6	12 6

* The difference is to women's advantage.

Railway F.

Age	Clerical Staff		Age	Clerical Staff	
	Women's Rates	Men's Rates		Women's Rates	Men's Rates
	s.	*s.*		*s.*	*s.*
16	12	12	22	24	30
17	14	16	23	26	32
18	16	20	24	28	54
19	18	24	25	30	36
20	20	26	26	30	38
21	22	28			

Clerical Staff—Women					
A—Clerks, Typists, and Tracers			B—Telegraph Clerks and Statistical Staff		
—	Principal Stations	Other Stations	—	Principal Stations	Other Stations
	s.	*s.*		*s.*	*s.*
Age 16 . .	12	10	Learners . .	6	6
17 . .	14	12	,, . .	8	8
18 . .	16	14	Age 16 . .	12	10
19 . .	18	16	17 . .	14	12
20 . .	20	18			
Maximum .	30	28	Maximum .	30	28
Supervisory posts	40	35	Supervisory posts	40	35

Men's Rates.

—	Ticket Collectors			Parcel Porters and Cloak Room Porters			Receiving Office Porters			
Class	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	4th
	s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1st year.	25	23	21	26	22	20	21	20	19	18
2nd ,, .	26	24	22	27	23	21	22	21	20	19
3rd ,, .	27	25	23	28	24		23	22	21	20
4th ,, .	28	26	24		25		24	23	22	21
5th ,, .							25	24		
6th ,, .							26			
Maximum	28	26	24	28	25	21	26	24	22	21

Other Transport.

Since the War, women have been increasingly employed as conductors on trams and motor buses in order to replace men who have enlisted. In the majority of cases the women are taken on at the same wage rates per hour as the men, though they work in shorter shifts—generally 6 hours instead of 8. They are found to be more satisfactory on 'single deckers' where the work is less arduous. The work seems to be popular with the women and also with the public. Women are not employed as drivers. In some towns they are employed in washing the cars.

Where women have been employed to drive heavy motor or horse vans they have not proved so successful as on lighter cars, and employers are averse to keeping them. They rarely have the necessary mechanical knowledge to attend to slight readjustments in the van, and the work is generally too heavy. As drivers of lighter cars, however, they have proved very successful and their employment as chauffeuses is likely to increase. Many doctors have taken women to drive their cars. As drivers of taxis on the streets, however, their employment has many objectionable features.

Clerical Work.

Commercial Clerks.—Summary of Distribution by Industry or Service, Census* 1911.

Industry or Service	Males	Females
Professional Occupations	3,521	1,319
Domestic Offices or Services	471	2,013
Commercial Occupations	56,150	7,584
Conveyance of Men, Goods, and Messages	14,223	865
Fishing	244	10
Mines and Quarries	17,793	1,167
Metals, Machines	52,564	12,436
Precious Metals, Jewellery	4,449	4,215
Building, &c.	9,764	1,408
Wood, Furniture, &c.	9,456	2,617
Brick, Cement, Pottery, and Glass	4,712	876
Chemicals, Oil, Grease, &c.	17,242	5,116
Skins, Leather, Hair, &c.	3,101	1,163
Paper, Prints, Books, &c.	18,467	8,652
Textile Fabrics	30,406	11,708
Dress	9,864	6,928
Food, Tobacco, Drink	48,387	21,052
Gas, Water, and Electrical Supply	6,312	166
Other General and Undefined	12,115	5,383
Industry or Service not stated	40,458	22,197
Totals	319,253	94,678

* Including various other commercial occupations.

In this group the Census figures for 1901 and 1911 show a total increase of 31·3 per cent.—17·1 per cent. increase of males and 109·8 per cent. increase of females. Clerical work is, indeed, one of those occupations which offer a considerable and widening sphere for the employment of women, and since the War there has been a very large addition to women clerical workers, many of whom will undoubtedly be retained. In industry proper, the first displacement of men by women has taken place almost without exception in the office staffs. In the past there has been a distinct tendency to give women the less responsible work, but more experience has shown employers that, with training, the peculiar qualities which women possess make them in many cases equal to or superior to men. In spite of this, in those occupations where the War has been the occasion for the first entry of women some adjustment has been made in the work in order to reduce the responsibilities of the women to a minimum; this is notably the case in banks. Where women have been taken on as bookkeepers the handling of heavy ledgers has sometimes proved a bar to their further employment.

Large numbers of women have been taken on since the War in Government departments, and by municipal and other local authorities. Generally speaking, women are given little opportunity of advancement or training, and in many

businesses their employment is limited to shorthand and typewriting. For various reasons, and largely because of the inferior status of women as workers, they are paid less wages than the men. The Clerks' Union demands the same wages (35*s*.) for men and women, though it is found in practice impossible to enforce it. Many employers state that women are often paid less wages than the men because they ask for less. A woman who asks for 25*s*. weekly may be very good or very inefficient. Those, however, who ask for 35*s*. are in almost every case extremely good workers and well trained, whereas men who ask for 35*s*. are often indifferent workers.

Evidence with regard to displacement (which is taking place to a considerable extent) is very difficult to collect, save in a very general way, and no attempt can yet be made to systematise it.

Banking.

Women were employed in banks only in exceedingly small numbers before the War. As 20 per cent. of the men in the London banks enlisted during the first three months of the War, it is to be expected that by now large numbers of women will have invaded this hitherto almost preserved field of employment.

In one bank the proportion of women has advanced from 4 per cent. to 20 per cent. of the whole staff, and taking thirteen representative banks it was found that 336 women had been supplied to them by one agency alone by the beginning of May, and that number has since been greatly increased.

But the vacancies caused by enlistment have not been by any means entirely filled by women; in the case quoted above from 5 per cent. to 10 per cent. of such vacancies were filled by men. In another, where 600 men enlisted, only 100 women have been substituted.

The women drawn into the banks have been mainly young (from 18 to 25) and of the secondary-school standard of education. At first only the quite young were accepted, but so great was the unemployment among middle-aged (thirty-five years) professional women that an attempt was made to persuade those responsible for the choice of women employees to try them. Where this counsel prevailed better results on the whole were obtained than in the case of the young girls, who frequently failed, perhaps through lack of confidence, in the test set, viz., the balancing of a page of a pass-book. The personnel therefore of this new army of bank clerks is very varied—from the girl fresh from home or school, through numbers with differing degrees of office experience, to women of training and experience, but in some totally different sphere of work such as private teaching.

Opinions differ somewhat widely as to the value and efficiency of the work done by women. By one manager the statement was made that as a whole women are more satisfactory than the men they have replaced, it being understood that they only replace men in the more mechanical and routine classes of work; another held them to be always inferior to men even after considerable training. It would seem to be agreed that generally women are most satisfactory in the simpler branches, doing such things as pass-book calculations, abstracting, and, of course, typing. Here they appear to compare favourably with men, and are often superior to youths. In a few instances more responsible positions have been given them, and with success, but this is not at all general.

Difficulties in employing women in banks have arisen mainly on account of accommodation, but a little arrangement has generally overcome these. Other objections have been put forward with more or less reason, as that women are less reliable owing to more frequent absences on account of illness. There would seem to be some justification for this. Insurance company figures show that between the ages of 21 and 40 women's absences are 15 per cent. as against men's 5¾ per cent., though below twenty-one years there is hardly any difference. Less credible would seem to be the theory that women may not be trusted with confidential matters.

The remuneration for women in banks is generally lower than for men. This seems to be chiefly a matter of custom, but it is also advanced that

woman's more frequent illness is in part a reason, also that the supposition that a man has more dependent on his salary influences the rate of his pay as compared with a woman's. So low have been the salaries offered to women by two well-known banks that employment bureaus have in some cases refused to send them applicants. This is, however, exceptional, and banks have been drawing women from insurance offices by offers of higher wages. Girls of seventeen mostly begin at 17*s*. 6*d*. a week, rising to 20*s*.; more experienced women may begin at 25*s*. or even 35*s*., but one investigator failed to find one woman earning more than 175*l*. per annum.

Men or women replacing Army recruits are taken on on a temporary basis, the places of men going to the Front being always kept open; but it is expected that a considerable number will not return to their old posts and that women taken on now are likely to remain.

Insurance.

Women had already been employed in insurance offices to a considerable extent before the War, and were easily substituted for men in many cases of enlistment. One firm's percentage of women rose from 8 per cent. to 10 per cent. of the staff and a further increase is anticipated. Where a permanent staff (pensionable) and a supernumerary staff have existed, women seem only to have belonged to the latter, and the work of men enlisting from the former has been distributed among the men on the latter. Women do mainly routine work, such as typing, shorthand, and simple clerical work; they have been considered less reliable than men and not able to deal satisfactorily with an influx of heavy work, and so are not found in the more important positions or on the permanent staff. They are mostly of ages ranging from seventeen to forty, and of the ordinary standard of school education. They pick up the work as they go along, or are taught by the older workers, and for what they do are found as quick and competent as men.

Women do not seem to have been tried as agents. Where 20,000 agents represent one company none are women, and it is not intended to try them. But in the district offices of the same company 77 more women have been employed since the War.

The payment is on a lower scale for women than for men; it is estimated at about 15 per cent. less than the average man's doing similar work. It is contended that women are less keen, and do not increase in value as do the men, also that they are much more uncertain in their attendance owing to inferior health.

Large numbers of women have been added to insurance staffs for National Insurance work. One staff alone includes 2,100 women, as compared with 1,700 men. Difficulty in accommodating women in old offices has been found, but large new buildings have in many cases been put up, and meet this obstacle.

No great eviction of women taken on now is expected after the War.

Local Authorities.

Replacement on a small scale has taken place under local authorities. following show the figures in the month of February 1915, compared July in the previous year:

—	Clerical Staff	
	Males	Females
Employed in July 1914	25,652	15,549
„ „ February 1915	24,286	16,144
Increase or Decrease	−1,366	+595
Known to have joined Forces . . .	3,620	
Net replacement	+2,254	

The extra women taken on have been almost entirely auxiliary clerks. Their employment is considered as temporary only and the scale of pay is sometimes the same, though generally slightly below that of the men displaced. In some cases local authorities are paying to the enlisted men their ordinary pay less Army allowance. In a few towns women are engaged as head office clerks, and in others they are employed as library assistants, in one case as the chief assistant (permanent). One town has employed a woman as a police inspector and another as a sanitary inspector in place of a man.

Women are also employed in some towns as street cleaners; they work 8 hours instead of 9 hours and are paid 4½*d.* per hour instead of 6*d.*

CIVIL SERVICE (investigated by Miss A. C. Franklin).

The work of the Civil Service is best considered under clerical work, as, save in the Post Office, the extra women who have been employed since the War have almost in all cases been taken on for work of a clerical nature.

It has been impossible to obtain information for all Government Departments, especially those such as the War Office and the Admiralty, in which the work of the War presses most heavily.

Since the War women have replaced men in several Government Departments, but precise information is very difficult to state, for in many of the offices duties have been so re-arranged that the responsible work has been divided amongst the senior members of the permanent staff—or by promotion—and women have only been taken on in the lower grades of the work. The proportion of enlistments, especially amongst the lower grades and in the Post Office, has been heavy—20 per cent. up to the middle of February—and places had up to February been filled by men and women up to four-fifths of those who had left. Much of the work of the higher branches is very technical and requires considerable experience as well as judgment, and it has been difficult in these branches to discover substitutes, with the result that enlistment in them has been discouraged from the beginning. Women are taken on in various ways; since May 9 the Civil Service Commission has sent women to various Departments; many Government offices have engaged women privately, from applications received by the Department officials or Ministers concerned or by personal recommendation—others have been engaged through the Labour Exchanges; some were women who had qualified by examination; others have had no experience. It was hoped that sufficient women could be obtained at the Treasury scale, but this has not proved to be the case, and there has been a distinct shortage of capable women willing to enter Government rather than private employment at the rates laid down.

Women clerks have been engaged in practically all Departments. The scale of wages laid down by the Treasury is as follows :—

For typing, operating duplicating machines and ordinary sorting or routine work, 18*s.* to 20*s.* a week, with overtime at the rate of 6*d.* an hour.

For ordinary clerical work, 21*s.* to 25*s.* a week, with overtime at the rate of 7*d.* an hour.

For shorthand-typing, 26*s.* a week, with overtime at the rate of 9*d.* an hour.

For higher clerical and supervising work, 30*s.* a week, with overtime at the rate of 9*d.* an hour. In normal circumstances clerical posts at this rate are only sanctioned in a proportion not exceeding one to five of those at the lower rate. The normal hours of attendance are determined by the Heads of Departments at their discretion, and are not less than 42 hours a week. Overtime of less than half an hour on any one day is not counted for the purpose of overtime payment. Ordinary leave on full pay may be allowed (subject to the exigencies of the Service) at the rate of one day for each month of service, as well as on the usual public holidays. Sick leave on full pay may be allowed up to a maximum of six weeks in the year, insurance contributions

being payable at the reduced rates prescribed by Section 47 of the National Insurance Act, 1911.

In answer to a question asking for details as to the number, conditions of service, age, etc., of the women employed in Government Departments under this scale, the Secretary to the Treasury replied on July 27, 1915, as follows :

'Appointments to temporary clerkships are usually made by heads of Departments at their discretion, and it would not be possible to ascertain the total number of women so appointed without making detailed inquiries which would take a considerable time, and in view of the constant fluctuation of work would not, I think, be of much value. In view, however, of the large number of temporary appointments authorised to replace junior members of the public service who were given permission to enlist, a special arrangement was recently made with the Civil Service Commissioners by which they keep a list of suitable candidates and assign them to Departments if requested. This arrangement has been largely (but not exclusively) used by Departments, and the number of appointments so made is as follows :

(1) Typing, duplicating, sorting, and routine work at 18*s.* to 20*s.* per week	74
(2) Ordinary clerical work at 21*s.* to 25*s.* per week	604
(3) Shorthand typist duties at 26*s.* per week	43
(4) Higher clerical and supervising work at 30*s.* per week	56

The average age of persons assigned for routine work on the 18*s.* to 20*s.* per week scale is between seventeen and nineteen. Some older candidates with limited qualifications have also been assigned to this grade. No limits have been definitely fixed for this or for any of the other grades.

The duties of the routine grade (1) are those commonly performed by boy clerks, female sorters, and female typists. 'Ordinary clerical work' (2) is such as is given to assistant clerks (abstractors) and junior Second Division clerks. The higher grade covers duties of a like character but involving some element of responsibility, *e.g.*, the supervision of work, &c. Besides these grades a few appointments have been made at higher rates for work requiring special qualifications and experience.

All these clerks are informed on assignment that the employment is strictly temporary and liable to termination at any time.

The Board of Agriculture especially has had considerable difficulty in obtaining the required number of women at the wage offered. The India Office has found it necessary to replace four men by five women. Since the War the Labour Exchanges have taken on between 800 and 900 extra women in clerical capacities. The War Office has engaged a number of women on new work as 'language' experts at 30*s.* to 3*l.* a week.

An exact comparison of men's and women's wages is difficult, as the men are all on a scale, and it is impossible to assess in real wages such assets as sick leave on full pay, free medical attendance (in the P.O.), pensions, &c. to which Civil Servants are entitled. The duties are often re-arranged, and it must be remembered that, with the exception of doctors, all women in the service are paid at a lower rate than the men.

All the Civil Service Unions urge that temporary work should be paid at a higher rate than permanent, as a safeguard, and that women should receive equal pay for equal work, but the men's Unions wish it to be certain that the work is really equal, otherwise deductions must be made—for favourable duties and hours, &c.

The Postal National Joint Committee asked that women substitutes should be paid the average salary of the men replaced. With regard to postmen, in actual fact women are paid less; if men are not obtainable at the lowest rate a higher rate can be paid, but women, if taken on, are only paid at the lowest rate. It is very difficult to calculate exactly what the women should be paid as, *e.g.*, 20 women recently replaced 12 postmen. On the average 10 per cent. less appears to be paid to temporary women clerks than to temporary male clerks. The view of the Service is that women should be paid less. The whole question

will, however, come up for discussion when the Report of the Civil Service Commission is published.

Departments which have been set up since the War, *e.g.*, the Ministry of Munitions, are employing a large number of women clerks, but these are not replacing men, though the proportion of women employed in such Departments is higher than in ordinary Government Departments, as they are organised on more modern lines than the older Departments.

The work of women clerks has been very satisfactory except in so far as the Treasury scale tends to attract inferior rather than superior workers. It is stated that the women engaged since the War have on the whole been superior to the men engaged in lower grades during that period.

Extra women are also employed as Post Office sorters, telegraphists, telephonists, and in London to a limited extent as postwomen.

Where women are now doing the work previously done by men, *e.g.*, sorting in the Post Office, the work has been so arranged that women do no night work, no heavy work, and they finish their work in time to reach their homes by public conveyance; where this has not been possible they have been sent home in taxis. Women telephonists employed on night duty are given beds in their rest room so that they can sleep three hours during their night's shift. The lack of adequate accommodation has been to a certain extent a deterrent to employing women, but such difficulties are not serious and have gradually been overcome. The identity of men's and women's work is often difficult to establish, and the information at present at our disposal is not sufficient to allow of our doing this with any adequacy.

Married women have been taken back, particularly in the Post Office, as telegraphists. There is a grievance that these married women are only paid the same as the temporary women and have not gone back to the salary they were receiving before they married, even if they are as efficient as before.

With regard to the higher branches of the Civil Service, as has already been noted, the experience and technical knowledge necessary have not encouraged Departments already understaffed and overworked to attempt experiments in the replacement of men by women save in the lower grades; though in this respect especially the traditions of the Service are wholly against the inclusion of women in such work, and the mere prejudice against the employment of women in the higher posts often biases and distorts judgment. Since the War one woman has been taken on in the Civil Service Commission in place of a First Division clerk, and is paid 2*l.* 10*s.* a week. At the Home Office an additional female factory inspector has also been appointed.

In reply to a question asking for information as to how far the places of male inspectors, who had enlisted or been transferred in the Service, had been filled by women, the Home Secretary stated on July 28, 1915, that 'Twenty-four inspectors and six assistants in all have been called up or have joined His Majesty's forces; 22 inspectors and 11 assistants have been lent for war service in other departments, 16 of whom are engaged in special work requiring technical qualifications under the Admiralty and Ministry of Munitions. The present strength is 157, as compared with 219 a year ago. I am considering the question of appointing temporary women inspectors for the period of the War, and one such has already been appointed, but temporary assistance can only be utilised to a limited extent, as a careful training is required before an inspector is able to undertake the full duties of the post, and the work of training and supervision of any considerable number would throw a heavy additional burden on the experienced inspectors and seriously interfere with their own work.'

In some places vacant inspectorate places have not been filled either by women or by promotion from the Lower Division. Either course seems equally against Civil Service traditions. All places of men enlisted are to be kept open for them, and as pensions, &c., are owing to them, they will be more likely to return to their posts than other men in private employment. If men are not able to return, quite possibly women will in future be employed to do the work, especially in the lower grades, but the question is bound up with the reorganisation that may come when the Civil Service Commission Report is considered. The Post Office intends to take on wounded soldiers to do messenger and other work, instead of women.

ENGINEERING AND THE METAL TRADES.

The metal trades apart from engineering do not appear in Table III. owing to the lack of available statistics. The following show, however, the state of employment in this group in February 1915 compared with July 1914 :

Trade	Approx. Indus. Pop. Census 1911		Net contraction or expansion (per cent.) in Feb. 1915 on nos. employed in July 1914	
	Males	Females	Males	Females
Small arms	6,000	*	− 6·6	+ 4·4
Scientific instruments	27,000	5,000	+ 1·2	+ 8·5
Wire drawing, chain, &c.	45,000	15,000	− 6·6	+ 4·4
Hardware	103,000	23,000	−14·1	+ 2·7
Musical instruments	28,000	6,000	−17·6	+ 2·5
Tinplate	23,000	3 000	−14·2	+ 1·4
Iron and steel	311,000	2,000	− 5·7	+ 0·2
Cutlery, tools, &c.	54,000	17,000	− 9·1	− 5·4
Other metals	104,000	20,000	− 8·8	− 6·5
Jewellery, watch and clock making	44,000	12,000	−27·9	−12·8

* The 1911 census shows only 300 women in this trade, but employers' returns showed 1,200 occupied in July 1914.

The most sweeping changes caused by the War demand have taken place in the various metal industries. It is these trades which have been able to adapt both their plant and their labour to the production of munitions of war. As this adaptation has been going on in very many firms, whose normal products are of the most varied nature, it is difficult to deal with industries in this group. Those firms which quickly adapted their products to the needs of the time soon employed largely increased numbers both of men and women, paying them abnormally high wages, both in the form of increased piece-rates and as payment for overtime. Any metal firms, therefore, which were slow in adapting their output to the needs of the country began in the winter and the early spring to find themselves short of labour, female as well as male. The position, then, is that a single group of industries, the manufacture of guns and ammunition of various types, has monopolised to an ever-increasing extent the premises, plant, and workpeople previously devoted to all the many metal trades.

Since a large proportion of the munitions now being made does not involve such heavy work as the products of the same factories in time of peace, the proportion of women employed has almost inevitably greatly increased. Many of the processes are such as women have commonly performed in recent years. In some works, moreover, such new plant as has been installed has been consciously chosen with a view to the employment of women on account of the scarcity of male labour. Most of the newly employed women, therefore, are not engaged upon processes previously performed only by men. The line of division, however, between male and female labour is always variable; and in many works it is moved so as to allow the employment of women on work previously thought to be just beyond their strength or skill. Instances of women being employed in work widely different from any undertaken by them in time of peace are comparatively rare, though they seem likely to multiply rapidly.

It is possible to group the metal trades roughly according to the proportion of female labour employed in time of peace, and to differentiate between the recent developments in each group.

1. *Trades which deal with Metal in its Rough and Heavier Stages, viz., Iron Casting, Metal Rolling, Sheet-iron Work, etc.*—In these trades women are not employed, and the War has not altered the position. The processes in many cases are identical with those in time of peace, since the product is turned out

in a comparatively early stage, and the fact that it is subsequently used for the manufacture of munitions only affects these firms by increasing the demand upon them.

2. *Trades requiring considerable strength and a High Level of Skill, viz., Engineering and Motor Building.*—In these trades the number of women employed in times of peace was very small, and some firms are even now not admitting them. The product has, however, largely changed, and very many shells are being made by them in workshops which have been adapted to this form of production and in departments recently built. Many firms which employed no women before are now taking them on for the manufacture of shells, and are employing them especially in their new workshops, in some of which the staff is entirely female, with the exception of a few skilled toolsetters.

3. *Trades requiring somewhat Lower but more Varied Degrees of Skill and Strength, viz., the Manufacture of Cycles, Bedsteads, Lamps, Brass Goods, etc.*—In these trades both men and women were employed before the War, the men usually performing the more skilled and heavier parts of the work. There has, however, been some considerable conflict over some processes, and policy has differed in different works. The line between men's and women's work is perhaps most variable in the cycle trade, on account of the comparatively recent invention of cycles and the rapid development in the methods of their production, making the trade largely independent of tradition. Such firms are now adapting their machinery to the manufacture of shells and fuses, and the new hands taken on are mainly women, on account of the shortage of men. The processes formerly worked alternatively by men and women are being increasingly undertaken by women, and they are making their way into many processes previously just beyond the line separating their work from that of the men.

4. *The Production of Small Metal Goods, viz., Pens, Buttons, Military Ornaments, etc.*—These have for many years been trades in which the greater number of the employees were women. A small number of men are employed as toolsetters, but the actual working of the machines or presses is left to women and girls. Therefore, though the output has been altered to meet the War demand, parts of cartridges and military buttons and ornaments being made, there has been very little alteration in the staff. Such replacement of men, therefore, as has taken place has been in firms devoted in time of peace to the industries which are grouped under the headings 2 and 3, though even here they are for the most part engaged on repetition work and automatic machinery involving little or no departure from the work to which they are ordinarily accustomed. They are employed in filling, capping and cleaning shells, boring and drilling bombs, and making cartridge cases and fuses of all kinds—English and French. For certain of these processes, such as the fine work required in the making of fuses, women are particularly suitable, and would probably have been employed even if male labour had been abundant. Where, however, as is the case in several factories, women are executing the entire process of shell-making from start to finish, involving (in the case of 8-inch high-explosive shells and Russian 3-inch shrapnel) 21 operations, they are doing work for much of which men would have been employed if they could have been obtained. Also, in a few exceptional cases, women are acting as fitters.

The following quotations from the 'Engineer' of August 20 show that in some works bold experiments in the wider employment of women have been tried.

'During the past few months,' says the writer, 'a great and far-reaching change has been effected. . . . In a certain factory which is engaged in the production of projectiles in sizes up to those required for 4·5-in. guns a new department was started some time ago, the workpeople being women, with a few expert men as overseers and teachers. . . . By no means all of the work has been of the repetition type, demanding little or no manipulative ability, but much of it has been of a character which taxed the intelligence of the operators in a high degree. Yet the work turned out has reached a high pitch of excellence. . . . It may safely be said that women can satisfactorily handle very much heavier pieces of metal than had previously been dreamt of.

Moreover, they have shown themselves capable of successfully carrying out arduous processes, such as forging, etc., which hitherto have only been performed by men, and of managing machine tools of a very different nature and requiring a very much higher standard of intellect than do automatic and semi-automatic tools. In fact, it can be stated with absolute truth that with the possible exception of the heaviest tools—and their inability to work even these has yet to be established—women have shown themselves perfectly capable of performing operations which hitherto have been exclusively carried out by men.'

Besides the replacement of men, there has also been a considerable replacement of boys by women in some processes. Many comparatively young lads are now engaged upon work of a kind which would certainly, in normal times, be entrusted to adult workmen. Such a process, therefore, as engraving, which would otherwise have been done by boys, is now undertaken by women, who are engraving dials on maxims, numbers on gun parts and shells, etc. Where a very high degree of accuracy is demanded, which can be tested by a purely mechanical operation, girls are often found to work better than boys or men, for the very reason which is thought to make them less valuable in processes requiring judgment. Girls, not having yet begun to take their industrial career as seriously as boys, frequently do not attempt to exercise their judgment with regard to their work. Since private judgment is only found to interfere with accuracy in a purely mechanical test, their work is, for this reason, more exact and satisfactory.

It is clear that an extension of employment of women in munition work is still possible, since in July last the number employed in this country, much as it had increased, was only between a fifth and a tenth of the number employed in France. The number in England was then, according to Mr. Lloyd George, 50,000, and, though it has grown very considerably since, there is still room for expansion. There are in France some women of really high skill in the engineering trade capable of looking after as many as three machines at once. At the same time the main obstacles to the further employment of women are stated to be very much the same in France as in England. The number employed as fitters is small, and on lathes and automatic machinery they require the supervision of a skilled mechanic to set up the work and prepare the tools. Their disabilities are doubtless due mainly to lack of training, but the proper training of a skilled mechanic is a slow process.

No comprehensive consideration of the question of wages is yet possible in these trades owing to the differences between localities and firms and the rapidly altering situation. It is clear, however, that in many cases the wages of women are decidedly lower than would have been paid to men doing similar work, though usually the work of men and women is not easily comparable.

Girls under 18 years of age are said in some instances to be receiving as little as 9*s*. per week and those over 21 years 15*s*. per week for work on which men have formerly received a minimum of 26*s*. In many places the prevailing rates are 10*s*. to 15*s*. for a 48-hour week. In almost all these instances, however, the women are learners and the wage they receive is a learner's wage, whilst the men were skilled workers whose output was considerable. Women are often working overtime, sometimes up to 73 hours per week, for which they are generally paid at time and a fifth, compared with the men's time and a half or even double time. In the districts where female labour is becoming scarce, however, a large proportion of the women munition workers are earning 30*s*. per week and upwards.

There are some firms in which the time-rates paid to women, though very much less than those paid to men, compare not unfavourably with them when considered in terms of piece-rates. Until women have had a somewhat longer experience, even in comparatively unskilled work, they are not likely to be able to work with the rapidity of practised workmen. Nevertheless, the rates paid to women are certainly inferior in the majority of cases to those paid to men. The poor pay of women in most occupations in normal times has given them a low standard, and makes them consider the wages which they are now receiving in many munitions works as phenomenally large, however unfavourably they may compare with the wages of the men in the same place.

The attention of Mr. Lloyd George has already been called to what is often a glaring disproportion between the wages of men and women in munitions, and

he has made certain promises after stating the necessary conditions to be considered in equating men's and women's wages. He insists first of all upon the need for instruction and training. He draws the necessary distinction between piece work and time work rates, though he agrees that during training the women in munition factories under Government control should be guaranteed a living minimum wage. He also states that it has been agreed that as far as the work is concerned women shall be paid exactly the same price as a man for any piece of work she turns out. 'The Government will see that there is no sweated labour.' 'We cannot give the same time rate, but the piece rate we can give as well as a fixed minimum which will guarantee that we shall not utilise the services of women merely to get cheap labour.'

The permanent effects of the War on the main metal trades will not, it may be feared, be beneficial. Till recent years the development of machinery and the subdivision of processes which accompanied it have led to the employment of an increasingly large proportion of unskilled and semi-skilled labour. Just before the War, however, there were signs that this process was being reversed, new developments in automatic machinery leading to the unskilled worker being displaced, while the skilled toolsetter was retained. That is to say, subdivision was still going on, but it was beginning to be subdivision between machines, not between human agents. This recent tendency towards the supervision by one worker of several automatic machines has been checked by shortage of skilled labour since the War. In some of the newly built departments, therefore, instead of the most modern automatic machinery, plant of a type requiring only an inferior degree of skill has been installed.

Appended is a separate Report on the manufacture of electrical apparatus and others on certain metal trades less immediately affected by the demand for munitions.

Electrical Apparatus.

(Investigated by Miss M. E. Bulkeley, Miss M. Cross, and Miss Moses.)

	1901			1911		
	Total	Men	Women	Total	Men	Women
Elect. cable manuf. .	—	—	—	5,813	4,858	955
,, lamps . . .	49,518	47,028	2,490	5,627	1,425	4,202
Other electric apparatus and electric fitters	—	—	—	54,746	50,558	4,118
				66,186	56,841	9,275

(The men's figures for 1901 include also electricians (undefined) who in 1911 = 27,905.)

Women are to some slight extent doing work which before the War was done by men, in certain departments such as :—

Small lathe work.
Screw machine.
Cable making.
Winching of transformers for armatures.

This last may be regarded as an extension of work previously done by women rather than as an entirely new process; for example, where they now wind two coils on to a transformer they previously only did one.

Before the War, women were employed in all branches of light work in electrical apparatus work, but not at all in the electrical supply trade. Although the above displacement is classed as owing to the War, there is evidence that before August 1914 the policy of many firms had been to extend the employment of women into new branches. That women have to some extent been replacing men, or at any rate entering new branches, may also be inferred from the fact that, though the electric lamp branch of the trade has been depressed owing to the War, there has been a total increase in the

employment of women in the electrical trade of nearly 18 per cent. Part of this increase is due to a temporary increase of production in branches of the trade in which women were previously employed, but as the enlistment of men from this trade has been on a considerable scale, it is reasonably clear that women are to some extent taking their place during the emergency. In most cases readjustment to meet the introduction of women has been simple, or no alterations at all have been necessary, as they have only been put on to the lighter machine work. One firm has actually made the machines more mechanical and employs an extra mechanic as supervisor.

The introduction of women into new processes often necessitates the provision of another workshop, as in the majority of cases it is not considered desirable for men and women to work together.

The main objections to the employment of women are :

1. Want of technical skill and general experience.
2. Want of physical strength, making it impossible to employ women on the heavier processes.
3. The strong objection on the part of many employers to have men and women working side by side in this trade.
4. In some cases the men's objection to the introduction of women.

In regard to the question of physical strength, one firm employing women in lathe making found the women's output slightly less than that of men, owing mainly to exhaustion during the last hour of work. Nevertheless it is clear that as a general rule women's output is considerably less than that of men, since both on time and piece rates their wages are generally 50 per cent. below those of men.

The main advantages are :—

1. Their greater dexterity in certain processes where small fingers are an advantage. This has been a considerable factor in the employment of women in such processes as assembly work in the electric lamp trade.
2. Cheapness of their labour.
3. The larger supply of unskilled workers to draw upon.

The Future of the Trade.—In those processes which are suitable to women, the possibilities of extending their employment are great. In the more skilled processes, however, where a longer training is necessary, it depends how far women choose to utilise the present opportunity of becoming highly efficient workers. Hitherto women have been employed almost entirely in unskilled processes, and the trade has been essentially one for young persons, the majority of the girls leaving the trade soon after the age of 19. It is difficult to foretell the state of trade after the War, but in view of the accumulation of private work which cannot be done at present, employers rely on its being good for at least a year or two, and they therefore expect to absorb the men returning from the Front as well as the new women that have been taken on. Two firms stated that after the War it was much more likely to be a case of taking on new men in addition than of dismissing the new women.

On the whole, there is little definite evidence up to the present of the actual displacement of men by women owing to the War, and the increase in the number of women is mainly due to a temporary increase of production. The trade unions, however, state that of recent years there has been an increasing tendency to bring women into the trade, and in view of the fact that the women are unorganised, they are pessimistic with regard to the future, fearing that the increase of female labour will lead to a fall in the standard of wages, and to male unemployment after the War. Much will depend upon the attitude of the women themselves.

The Metal Trades less immediately affected by the demand for Munitions.

Although those firms which are still mainly engaged in the manufacture of metal goods other than munitions are for the most part employing a smaller number of workpeople than before the War, they are only in a few exceptional instances suffering from a restricted demand. For the most part the main difficulty is the shortage of labour, and this is greatly aggravated in those

trades which suffered seriously in the first few months of the War, as the workpeople who left them then can frequently not be persuaded to return. In the trades that are not working on Government orders many of the employees left to enter munitions and similar work, from motives of patriotism, and were in some cases encouraged to do so by patriotic employers. There are several industries which are at work on necessaries for the Army, which are nevertheless shorthanded, partly because the produce is not quite so urgently required, and therefore not quite so highly paid, as munitions, and partly because the patriotic workpeople feel more satisfied when employed upon 'something which explodes.'

In those areas in which the production of munitions is being actively carried on there is a decided shortage of women in other trades which, though less pronounced than the shortage of men, is nevertheless sufficient to prevent much of the substitution of women for men which might otherwise have taken place.

Scientific and Optical Instrument Making.

In scientific and optical instrument making enlistment since February caused a net contraction of employment in the trade, and a demand arose for the labour both of men and women. The percentage increase of women has probably trebled since February. The women have been drawn largely from such trades as jewellery, clock and barometer making, silversmiths, and a variety of less relevant trades such as dressmaking. It is ascertained that in some instances women are actually doing work previously done by men, *e.g.*, the polishing of lenses. The present increase in the employment of women, or more precisely of girls, in the trade, however, is due mainly to the temporary boom, as for instance in clinical thermometers, test tubes, &c., and to the shortage of boy labour for these trades, and consequently may have little permanent significance. There are further opportunities in certain operations other than repetitive, as for instance light mounting of microscopes, &c., in the optical trade. Any considerable revival of the optical trade in England would open up a very large field for the employment of women, who do almost the whole work of this trade in the vast American factories. Opinions differ in regard to the employability of women in the various branches, mathematical, scientific, surgical, and optical, of the instrument trade. Much of this work is very highly skilled, and requires a long training, such as women in the past have not usually been prepared to face.

Jewellery.[16]

During the first six months of the War there was more unemployment in the more highly skilled branches of the jewellery trade than in any other Birmingham industry. The cheaper branches of the trade, however, in which women were most largely employed, were never as seriously depressed. In September the production of patriotic badges was being carried on more actively than most industries of the town. During the winter there was great improvement in the trade as a whole, but more especially in the less costly and less skilled branches. The demand for inexpensive brooches, bracelets, and other ornaments soon became good, and that for badges worn by men employed on Government work very brisk. With the approach of autumn, in which season the trade is normally at its busiest, the demand in most departments has revived considerably.

There is now a very decided shortage of both male and female labour. The supply of women is less scanty than that of men, since the men have not only been drawn off to the Army, and other trades, but were definitely dismissed from jewellery firms through shortness of work in the autumn to a much greater extent than the women. The proportion of women and girls employed is probably higher than it has ever been. We find indeed that although the processes which were already performed by women are the most active and are employing large numbers, there are also a good many women doing work of a kind done previously almost entirely by men. They are now, in a considerable number of firms, 'making up' the jewellery, that is to say fitting together

[16] This and the two following Reports relate mainly to conditions in Birmingham and the Midlands.

the parts, which work was formerly considered for the most part too intricate for them.

It is impossible to forecast the future of a trade which depends upon a luxury demand. If the industry continues to be carried on in Birmingham as extensively as before there is little doubt that women will retain much of the ground they have gained. Men who desire to return will be reinstated if they have not so hardened their hands by other work as to unfit them for the delicate processes of the jewellery trade, but it is expected that many will be permanently lost to the industry. Since, moreover, the average working years of a woman are much longer in this than in most other local industries, a training of some length should be possible for the girls where necessary. On the other hand, the difference of class which made the jewellery trade more attractive than the other metal industries has largely broken down as a result of the War, and it is believed that many girls as well as men have lost their taste for this occupation. This is perhaps not to be regretted until the future prospects of the trade are somewhat more assured.

Electro Plate.

The electro-plate trade suffered severely from lack of demand in the early months of the War, but now suffers mainly from lack of labour, both male and female.

There are certain processes (soldering, shaping, and polishing) in which women are being employed to a greater extent than before. There would probably, however, have been much more replacement if female labour were more abundant.

Hollow Ware.

The hollow-ware trade is suffering from lack of labour, both male and female. The shortage of men is greater than that of women, and considerably more overtime is being put in by the men, especially by those most highly skilled. Certain processes are now being done by women on machines which were formerly done by men by hand. The total number of women is, however, decidedly less than before the War, so that if the trade is anywhere near normal when the War is over there should be no unemployment. If there is difficulty in reinstating the men who return, it will be rather the result of the falling off of Government orders than the competition of women.

LEATHER.

The following shows the distribution of the numbers of men and women employed in the leather trades 1901 and 1911 :

—	Census 1901			Census 1911			Per Cent. Increase or Decrease		
	Persons	Males	Females	Persons	Males	Females	P	M.	F.
Total .	79,386	64,987	14 399	83,729	65,891	17,838	+ 5·5	+ 1·3	+23·9
Furriers and Skinners	9,731	5,876	3,855	14,199	8,526	5,673	+45·9	+45·1	+45·9
Tanners .	9,608	9,537	71	10,606	10,569	37	+10·4	+10·7	−47
Curriers and Leather goods manuf'rs	29,363	23,620	5,743	16,321 18,215	15,256 10,629	1,065 7,586			
				34,536	25,885	8,651	+17·6	+ 9·5	+50·8
Saddlers .	30,684	25,954	4,730	24,388	20,911	3,477	−20·5	−19·4	−26·5
Boot and Shoe	218,581	174,806	43,775	202,510	160,087	42 423	− 7·4	− 8·4	− 3·1
Slippers .	4,348	2,999	1,349	5,260	3,279	1,981	+21·0	+ 9·3	+46·8

The following notes on the trade, which were drawn up for the most part by Miss M. Stettauer, give some picture of the trade and indicate those processes in the different branches in which women were employed (*a*) before the War, (*b*) since :

A. *Tanning and Dressing of Leathers.*

Women very little employed.

Tanners' and curriers' work is much too heavy and entirely unsuitable for women.

In light leather dressing and finishing some processes are quite suitable, but it has been mainly a question of prejudice, and if only employers get sufficiently pushed for labour they will resort to female labour. This has already become fairly common in the large provincial towns—before the War even—but in London the factor appears to be almost negligible.

Processes.

Before the War, women were to a small extent to be found in Dyeing and Blacking.

Since the War, they have been introduced into

Mainly on fancy leathers and small skins	Seasoning	
	Embossing	(Skilled)
	Sorting	(Only just starting)
	Measuring.	

Women would be suitable also for such processes as washing, oiling, and tacking up. This last process is fairly widely done by women in Nottingham, who are paid 1½*d.* per dozen for tacking up. (Men in London receive about three times this wage for tacking up.)

Efficiency.

Women's work said to be satisfactory, slower, but perhaps on the whole more reliable and regular than that of men. In this branch of the trade, where it is physically possible to introduce women, there is no reason why the efficiency should not become as great, after a fairly short training. (In sorting a good deal of practice and judgment is required.)

Extent of Extra Employment.

In a firm where substitution has taken place to a certain extent :

In June 1914 4·86 per cent. of the employees were women.
In June 1915 10·68 per cent. of the employees were women.

Or put in a different form :

June 1915 there were twice as many women in the firm as in June 1914.
June 1915 there were 81·8 per cent. of the men there were in June 1914.
Total number of employees in this firm at present, 206.

N.B.—All the women introduced into this firm since the War are on leather finishing and dressing, before done by men, and no women did this work before, but there appear to be few London firms where substitution has taken place to anything like this extent.

Wages.

The introduction of women is not very general, and seems to be confined to comparatively few firms. Where it has happened women as a rule receive a lower rate. The following reasons are given :

(*a*) They have their limitations, *i.e.*, in the employment of male labour men can be selected for more valuable positions and for duties which women could not perform, *i.e.*, men regarded as a more permanent asset to the firm.
(*b*) They do less work. (Even the piece rate appears to be lower though.)
(*c*) They do not require, expect, or ask for so much money.

Objections put forward by Employers.

(1) A large proportion of leather tanning and dressing unsuitable for women.
(2) Difficulty in finding town girls who have the physique for the rougher kind of work which (even in the lighter branches) requires a certain amount of hard manual labour.
(3) Lack of accommodation.
(4) Difficulties in working overtime, permission only being granted when working on War contracts.

Objections from the Men.

This seems to be a serious point, and various opinions are put forward :

(*a*) Some employers say they cannot risk friction with the men now owing to the impossibility of replacing them.
(*b*) Others say that the present would be a good time for introducing women, as there is likely to be less objection than in normal times. Once women were admitted the difficulties after the War would not be so great.
(*c*) The opinion is also expressed that there is not yet sufficient shortage of male labour ; employers put off the introduction of women as long as possible, and the men will keep up the objections until the time comes when one process is actually held up for want of labour in the preceding process.
(*d*) Mixing male and female labour in the same factory.

Previous Employment.

So far, of the women introduced most were not in the leather trade before, about half were from various trades, some were not previously in industry, a few from domestic service. Mostly women aged 18-30.

Question of Permanence.

In this branch of the leather trade those few firms that have introduced female labour since the War are inclined to think the employment will be permanent.
The following opinions are given :

(1) Although the men who have joined the Forces will be re-engaged after the War, it does not follow that they will in every case be employed on the same work, *i.e.*, the women may not be pushed out of their present jobs, and possibly the present indifferent workers, both male and female, will be dismissed, and thus room made both for the good female workers at present employed and the men returning.
(2) If women once get installed in this branch of the trade it may be an economy to keep them after the War (even if it is not now, owing to the comparatively high wages they can now command).
(3) The percentage of men returning will, in all probability, be small.
(4) The slump in the trade may not be as great as is generally expected, especially not in this branch, on which the boot trade depends. As many firms are exclusively working for the Government the reserve stock of boots and shoes is gradually being depleted, and will be very low at the end of the War, and will need replenishing as soon as possible, *i.e.*, there may be more work available than is expected (after the War), and therefore perhaps no real reason why there should not be some permanent scope for women once they get into the trade.
(5) Plenty of work available for men and women too, after the War, if only cheap German goods were excluded by tariff.

Some firms in the heavy branches are experiencing a severe shortage of labour, and would be only too glad if women were physically capable of doing the work, *e.g.*, one firm has lost 30 per cent. of its men. It is heavy, dirty work, *i.e.*, tanners and curriers, and the men have gone (not only owing to enlistment) but also owing to the increased volume of employment available, which tempts them to leave dirty work if they can find clean. An isolated firm

or two in the provinces have put women into the tanneries, but it is only a particularly rough sort who would do it, and is quite impracticable on a large scale.

B. *Boot and Shoe Trade.*

Women largely employed for years, in certain parts of the work, but very little substitution owing to the War. Most of women labour in London now and before the War.

Processes.—Before the War.

Main province for women's work is the entire making of the upper after it has been cut out, *i.e.*, machining, shiving, fitting, closing, lining, eyelet machining, &c. Also inking and colouring. In one firm women have done machine clicking for years, but this is very exceptional.

Processes.—Since the War.

In some firms women have for the first time been put on to such processes as :

cutting heels,
* cutting out and sorting socks,
* putting in lasts,
sandpapering soles,
* lacing uppers with string,
clamping on heels,
riveting the in-soles,

* These jobs were in some cases formerly done by boys.

but these are mainly preparatory or subsidiary processes, and the main processes in the making of the shoe (excepting the uppers, see above), namely clicking, making the soles, lasting, and finishing, remain exclusively the work of men, and there is no immediate prospect of any change.

There is some scope for women in a few processes which are new and only in demand for the period of the War, *i.e.*, making, nailing, and quilting half-soles ready to be sent to the Front, special repairs to heels, &c. Here, women were put on to the work as soon as the machines were installed, and there was no question of men being put on to the work which is very easily and quickly learnt.

Efficiency.

In the few processes where women have replaced men (or boys) in some cases the efficiency appeared to be as great, and in fact women were found to be earning more on the same piece rate than men on the same job, as they 'stuck to it more.' On the other hand, in some cases they were said to be slower, though steadier and more regular.

N.B.—Where the slowness was most complained of was where the experiment of girls' work was newest, and where (see above) the woman could fully hold her own in the work she had been in the trade before the War, on a different process, so that the probability is that increased experience would approximately equalise the efficiency, but of course none of the processes enumerated above are at all highly skilled.

Extent of Extra Employment.

On the whole the extent of substitution is probably very small—in one large firm the substitution amounted approximately to 3 per cent., although about 10 to 12 per cent. of the staff consisted of women doing new (and temporary) processes. Many firms have had no change at all.

Wages.

The whole thing is on so small a scale that it is difficult to get much definite information. In one case the women were being paid at the same rate as the

men, in another it was said that the women were still 'being trained' and no definite rate had been fixed.

Previous Employment.

The majority of women who have come into the trade (either to new processes, or to processes formerly performed by men) were not previously in the trade, but were engaged in serving in shops, domestic service, tea-packing, one from an asbestos factory (put to cutting heels, as her former experience in cutting up material was found to be helpful for the new work). In one firm the small number of women who were to take on men's jobs were selected from women already in the firm working on 'uppers' before the War. In some cases girls have been taken straight from school to replace boys who have either left or been put on to more skilled work.

Training.

The new processes have been taught the women in the factory, but they are simple, and in general an average girl can reach her maximum in one to two weeks, *e.g.*, one girl nailing half-soles came into the trade, having formerly served in a sweet shop (and earned 12*s.* weekly), and at the end of one week was earning 2*l.* She has been earning at this rate for several months. This girl was not exceptional.

Where women have been actually substituted for men or boys the work is in no case highly skilled, and is such that it can be learned in the factory without detriment to material.

Question of Permanence.

As far as the replacement of men by women is concerned, the question of the men returning is hardly a practical one as the percentage replaced is so small. Women who have been introduced for new 'war' processes will, of course, have to go, but as a whole their 'market value' will probably be considerably increased (and therefore their ability to 'hold their own') as they will have learnt to work to time and to 'speed up,' which, coming from purely time work jobs, such as domestic service, and shop service, they would not have been able to do before.

Reasons why there has been little Substitution and comparatively little Alteration in the Demand for Female Labour in the Boot and Shoe Trade.

(1) The increased demand for boots since the War has been for heavy Army boots, and these are practically entirely made by men.
  (*a*) Because the machining on Army boots is heavy, and is not generally done by women, though except for the actual weight of the work, there is no real reason why it should not be done by women.
  (*b*) Because even where it is, or if it were, done by women the actual amount of machining to be done on the boot is very much less than on the ordinary light boot, as there are fewer seams, *i.e.*, the scope for what is normally the women's branch of the work is smaller.

(2) In the light boot trade there has been practically no entry of women into men's works for two main reasons :
  (*a*) Organised and very emphatic resistance from the men.
  (*b*) The work very skilled and requires long training. Parts of it, notably lasting and finishing, much too heavy and laborious.

War Emergency Conditions of Employment of Female Labour in Substitution for Male Labour.

At a Conference of Representatives of the Manufacturers' Federation and the Operatives' Union, held at the invitation and under the Presidency of Sir G. R. Askwith, K.C.B., K.C., Chief Industrial Commissioner of the Board of Trade, on June 3, 1915, to consider the situation that had arisen in the boot

and shoe manufacturing industry consequent upon the serious depletion of male labour through enlistment, it was mutually agreed as follows :

1. That females may reasonably be employed upon certain operations hitherto ordinarily restricted to male labour.
2. That the employment of females shall be limited to such operations as they are physically fit to perform.
3. That females so employed shall be paid the same rates of wages as are now paid to males for an equivalent quantity of work.
4. That due regard shall be paid to the desirability, where possible, of separate working conditions where male and female operatives are employed in the same department.
5. That no female shall be employed in substitution for male labour without previous consultation with the local Trade Union officials, and in the event of disagreement the question shall be referred to the Standing Committee of the National Conference for settlement.
6. That it is understood female operatives shall only be engaged in substitution for male labour where and so long as it is not found possible to obtain male operatives.
7. That this agreement is an emergency provision and shall have effect only during the continuance of the present War.

It has been difficult to obtain adequate information with regard to wages, the Trade Unions themselves furnishing little besides general complaints, which though perhaps capable of substantiation yet lack so far the necessary particular evidence.

C. *Leather Goods Manufacture.*

Trunks, bags, and general leather goods, including (now) military equipment, harness, &c.

(1) LONDON.

It is in this branch of the leather trade that the great increase in the employment of women is to be found, mainly in the actual military work, but here again the actual substitution that has taken place is practically nil. The increase is due simply to the enormous increase in the amount of work to be done and consequently in the demand for labour.

Processes.

Before the War women were employed on the following processes : machining and stitching (*i.e.*, including welting on bags) ; lining, stiffening (on bags) ; some strapping (*i.e.*, stitching in buckles and inserting locks) ; closing (*i.e.*, on attaché cases).

Since the War, women have to a small extent been introduced into riveting, and are doing a few subsidiary processes such as were done by men before the War, *e.g.*, punching holes in haversacks, also riveting bandoliers, but on too small a scale to have any practical effect on the trade.

The main feature of women's work in the trade is, however, the huge influx of women into it on processes which have for years been largely regarded as 'women's' branch of the work, *i.e.*, on the present work there is no question of substitution or replacement, though there may be indirect effects afterwards.

Efficiency.

As far as substitution is concerned the efficiency of women seems lower, *e.g.*, riveting is probably the lightest of the processes hitherto regarded as men's, but even here, women do not seem to have the same grip over the tools ; in one large firm it is reckoned that a man will probably make almost twice as much as a woman on the same piece rate at this work, and it is unlikely that

experience will remove the inferiority to any great extent. In another case an experiment in teaching riveting to women was being made, but the work was found a little hard physically, though not impossible.

It seems clear that the extension of women's work has been in those processes which were women's before, *i.e.*, machining and hand stitching, and here—in the case of women entering the trade since the War—it is found that in the average woman or girl the efficiency becomes moderately good in from four to five weeks' training. (See note on training.)

Extent of Extra Employment.

The 'substitution' numbers are exceedingly small—in one large firm employed on Government work the percentage of women employed on men's work is about 2½ per cent., but there are five times as many women employed in women's 'normal' processes as last year, and about 4·5 per cent. as many men. Total number of employees in this firm is now 2,800. In another firm (total number of employees now 620), also engaged on military work, the number of employees is nearly double what it was last year. The increase was made up in about the following rates : 92 per cent. of increase are women and the rest men. Here, however, there is a serious shortage of male labour, and an attempt is being made to train women in riveting. In yet another firm the increase in labour since last year (owing to military work) is 30 per cent. more men, 200 per cent. more women.

On the whole, numbers are misleading in this branch, as in hardly any case have firms been able to keep their civil and military work separate, *i.e.*, in some large firms all the private work has ceased, and therefore not only are the new 'entries' into the trade engaged on military work, but those who were already in the firm before have been turned on to it as well. On the other hand, some are doing contracts for the Government intermittently, *e.g.*, one firm (not one of those quoted above) reckons that on its normal work (trunks) 15 per cent. of the staff consists of women, mainly lining. When the War contracts come in, these women are not disturbed or displaced, but a large extra staff of women stitchers and machinists is engaged for the period of the contract and then leave again. What happens to the women between the contracts the firm cannot say; they probably drift into other temporary work.

Previous Employment.

A large proportion of the girls who have entered the trade are from other factories, *e.g.*, jam and biscuit, having no previous experience of leather work, but some firms have selected the girls they choose to teach with reference to their previous employment—*i.e.*, showing preference to those who could machine well before. Very good results, however, have resulted in the case of those who had no previous experience of a similar trade.

Training.

Where women are being introduced into stitching and machining, it is, as a rule, necessary to teach them in a separate department in order that they may practise on cheap bits of material. This is done in some of the large firms both for stitching and (to a small extent) for riveting. The women become proficient in stitching in about five weeks. One firm has trained nearly 1,000 women in stitching since the War, paying them 2*d.* an hour while they learn.

There is very little unskilled work to be done, though the training schemes are quite a temporary measure during the War.

Question of Permanence.

Here again the substitution question is on so small a scale as not to be a practical point with reference to the men returning, but the work is, for the present, regarded as of a more or less temporary nature, perhaps because (*e.g.*, in riveting) women have not yet had much experience, or it is too early for

employers to say yet whether they consider the work so inferior as to be merely a 'make-shift' during the present shortage, or whether there is any permanent scope for it; they seemed doubtful and undecided about it.

The question of the women stitchers, &c., who have been attracted into the trade since the War is, of course, much more serious, and there is a serious possibility of there being no scope for them when the Government contracts are over and many will have to leave the trade. Some employers regard the whole thing as a purely temporary inflation of the demand for women in the trade, and consider that after the War, not only will the War entrants into the trade have to go, but a considerable time will elapse before private connections are re-established, and in the meantime there may be a slump which will involve even a dismissal of a proportion of the pre-War staff. However this view is not universal, and it is possible that other counteracting factors might enter into consideration, tending to increase the scope for women's work in this branch after the War. It would depend on the state of foreign trade and on many other far-reaching considerations which it is impossible to foresee.

Reasons for very Limited Substitution.

(1) Most articles require stitching or machining, and this has been for some years past women's work, *i.e.*, in a large proportion of the firms here dealt with, women had been introduced long before the War, and the initial prejudice having therefore been overcome their employment had in most cases been 'pushed' up to the limit, that limit depending largely only on physical ability—where women had not ever been used before it was as a rule because the whole article was too heavy.

(2) There would be considerable scope for the employment of women in the trunk trade, but there is great resistance from the men, who are independent at present, as they know they cannot be replaced—if there were a still greater shortage of labour than there is now they might consent to it, as they would be 'held' up in some processes through lack of labour in others.

(3) Most of the men's work (especially in bags and portmanteaux) is highly skilled, and mainly constructive, *i.e.*, can only be handled after long experience. If girls were apprenticed to the trade in the same way as boys there is a possibility that they might ultimately become skilled workers in the men's jobs, though they would have to be carefully selected for strength and physique, as the majority of the work is undoubtedly too heavy for the average woman. However, as long experience and training would be required there could be no question of substitution in connection with a 'War' scarcity of labour. Employers state that from a business point of view it would pay them better to refuse orders than to undertake such training schemes for a temporary purpose.

Variation and Shifting of the Demand for Labour in Different Branches of the Leather Trade.

The increased demand for labour in the leather trade since the War has, of course, been in those branches that are working on War contracts, *i.e.*, initially there would be an increase of labour required in the tanning and dressing of heavy leather. Here (as already stated) there is no scope for women at all, and it is fair to say that, however great the shortage of labour might become, the place of men could never be filled by women in this branch.

Again, in the boot trade, the great increase in the demand has been for heavy Army boots, and here, again, the demand can only be supplied by women's work to a very small extent. On the other hand, in those firms where the bulk of the work is at present Army work, the amount of work available for women would tend to decrease (owing to the large extent to which the Army boot is made by men). In any case, there has been a very considerable tendency for women to leave the light boot trade and to go into the military equipment work. Women's wages in the boot trade are not particularly good, and the present high wages to be obtained at equipment work are a great attraction. Skilled women from the boot trade would, of course, be more readily taken on for military work than women coming into the trade for the first time. This

tendency has been much greater than the possible temporary decrease of employment available for women in certain firms would account for. In fact, there is considered to be scope for introducing fresh women to the boot upper trade, and at least one scheme exists and is in process at the Cordwainers' College, London, for training women in fitting and closing, &c. These women are taken mainly from the bookbinding trade, in which there is at present a certain lack of employment, and the scheme is found to be very successful, the women being easily placed when trained

In the general manufacture of leather goods, there has been a tendency for women to shift from those firms where work was slack to those engaged on Army work, *i.e.*, at the present time this would roughly mean a shifting from small to large firms, as there do not appear to be many large firms not engaged on Army work.

To sum up, the greatest demand for women's work in the leather trade is in the military equipment branch. It is supplied :

(*a*) To a certain extent from other firms that are slack, in the trade.
(*b*) To a certain extent from light boot trade.
(*c*) Largely from outside.

(2) BIRMINGHAM.

Apart from the actual production of munitions, the leather goods trade has benefited from the War to a much greater extent than any other. There is some increase even in the male labour employed. The number leaving to enlist has been small, largely because the proportion of men of military age employed in this trade has for long been less than in most others. This is due to the fact that the output of saddles and other heavier goods, the only branch of the industry in which men are largely employed, has been small since the close of the South African War, and, therefore, very few young men have entered this occupation.

The employment of women in the leather trade has increased to a very much greater extent than that of men. The large proportion of women, however, is not mainly the result of the substitution of female for male labour in definite processes. For years, with the introduction of lighter machinery and greater division of labour, an increasing proportion of leather work has been performed by women. This movement has been accelerated by the War and especially by the introduction of new machines, worked by women, to perform processes which men previously did by hand. Even now, however, the proportion of work done by men is considerably larger than the respective numbers of men and women employed would suggest, as, owing to the shortage of skilled labour, more overtime is being worked by the men than by the women. Although the processes performed by women in the leather trade are not of the highest order of skill, judged by the standards of male labour, yet they take some time to learn. The learning period is decidedly costly to the firm on account of the material damaged by the inexperienced hands. Early in the autumn one large firm showed considerable foresight in transferring a hundred girls from the manufacture of golf balls to the leather stitching department; the immediate loss to the firm was about 100*l.*, but the advantage since has been great. During the course of the winter an increasing number of girls has been drawn from other work to the leather trade, and though it is estimated to take about a year for girls to become fully proficient many of them are already earning comparatively high wages.

As a precautionary measure one firm is training a few girls in the heavier cutting processes, so that they may be able to take the places of men if more of these leave the trade. Training schools have also been established in London and elsewhere.

There is unfortunately little doubt that there will be a great deal of unemployment in this trade at the close of the War; this will be due, not mainly to competition between men and women, but to the great diminution in the demand for leather goods. Such a period of slackness of trade and considerable unemployment in the leather industry followed the South African War. It is to be feared that the greater output during this War may make the subsequent restriction of business even more serious.

TAILORING TRADE.

The following shows the increase of employment in the tailoring trade over the ten years, 1901 to 1911 :—

Census 1901			Census 1911			Increase or decrease %		
Females	Males	Total	Females	Males	Total	Females	Males	Total
117,640	119,545	237,185	127,115	122,352	249,467	+8·1	+2·3	+5·2

Tailoring is a term applied to the making up of various qualities and kinds of outer garments—male and female—ranging from best bespoke work, *e.g.*, men's Court and dress suits, to Kaffir clothing, which is shipped mainly to South Africa, and cheap dungarees such as workmen's overalls. The trade now employs about 143,000 women, and since the War this number has been increased by about 20,000, while the total number of men employed has decreased by almost 10 per cent. In no other trade save munitions has the increased employment of women been more marked since the War. It is impossible, however, to talk in terms of the trade as a whole, and it is necessary to distinguish its various branches in order to appreciate the nature of the increase of women's employment. The trade may perhaps conveniently be classified into the following branches :

Men's Retail Bespoke ranges from Court and dress suits to high-class suits made to measure. This part of the trade employs almost entirely skilled male labour. In the very best work the suit is made practically throughout, mostly by hand, by one person—the individual system. Most of the work is, however, done on the sectional system (sub-division of labour—cutting, basting, machining, pressing, and finishing). The War affected this part of the trade first, and it has never recovered from the depression, save temporarily for a few weeks during the height of the Spring season. Orders for officers' uniforms have partially counterbalanced the loss of civilian trade. The men who have left the tailoring trade almost all belonged to this branch.

Ladies' Bespoke.—Much of what applies to men's bespoke work applies to this branch of the trade, though generally speaking the work is lighter. It is for the most part a man's trade and, like men's retail bespoke work, needs considerable experience and skill. The War has caused a considerable depression in this part of the trade.

Ready Made and Wholesale Bespoke.—Ready-made work is cheap work done to stock sizes and supplied to retail shops or to merchants abroad. Wholesale bespoke consists of either 'ready-made altered to fit' or of orders for a comparatively cheap class of work, for which individual measurements are taken and passed on to the factory or workshop by retail shops or 'tally-men' who obtain orders from door to door in working-class neighbourhoods. In this work the cost of production is very much lower than in the retail bespoke branch of the trade, and depends to a large extent upon the use of machinery and power and a highly evolved sub-divisional system, while the work employs (at any rate in the factories) a large proportion of female labour (about 85 per cent.). The work is done either in factories or in small (mostly Jewish) workshops, to which it is almost always sub-contracted from the factories or wholesale agents. The chief centres of this branch of the trade are London, Leeds, Norwich, Manchester, and Bristol. There is a larger proportion of small workshops in London than in the North of England, and provincial centres of the trade such as Norwich employ a greater proportion of female labour, owing probably to the fewer alternative avenues for women's employment to be found in these centres. London is the centre in which the small master or sub-contractor with his workshop flourishes, and he has played a large part in the making up of khaki clothing. He is generally a Jew, and normally does the lower class of retail bespoke and the better class of wholesale bespoke work, and though he employs in proportion less female labour than the factories, he is able, owing to the skill and speed of his workmen and the way in which he organises and sub-divides his work, successfully to compete with the factory save on the cheaper grades of work.

Medium and Juvenile Tailoring.—This branch of the trade consists of the making of cheap grades of trousers and waistcoats (which comprise almost a separate branch of the trade) and boys' and children's outer garments. It is a slightly lower grade of work than the wholesale bespoke and employs almost entirely women and girls.

Export Work or Shipping or Slop Trade.—This branch of the trade consists of exceedingly cheap ready-made garments exported to be sold to natives in South Africa and elsewhere. It also includes dungarees such as workmen's overalls, and drills such as surgeons' coats, and cheap cotton clothing, most of which is exported. Women mainly are employed in the making of these goods.

The above divisions are not clear-cut, and the lower grade the trade the more difficult it becomes to demarcate labour or process. It will be noticed that, generally speaking, the higher-grade work employs a greater proportion of men than the lower grade and depends less upon machinery and more upon skill and experience.

During August 1914 a general depression set in throughout the tailoring trade which showed itself most in those parts of the trade dependent upon private orders, *e.g.*, the retail bespoke and to a certain extent the wholesale bespoke trade. Shipping orders (the lower-class trade) also began to fall off, not only because of a slackening in demand and temporary difficulties common to exporters with regard to credit, but because of the shortage of shipping. Owing to Government measures the balance of trade soon readjusted itself and the demand for clothing from merchants abroad increased, due to good prospects of the harvest in South Africa and to the cessation of Austrian and German competition, but the shortage of shipping nevertheless remained a factor which prevented export of goods in their normal quantities.

The wholesale bespoke ready-made and medium branches of the trade were probably less affected by the depression than the other branches, though even here a considerable contraction of trade occurred. During September and October, however, War Office and Territorial orders had the effect of more than restoring this part of the trade to its normal proportions. Khaki became the deciding factor affecting not only the large factories but also the sub-contracting workshops, for with the enormous increase of Government orders restrictions such as those affecting sub-contracting were relaxed. In normal times the military tunic and great-coat can be made up only by experienced and special labour. Owing to a certain extent to the dislocation of the trade and the shortage of cloth, but in a greater measure to the fact that few manufacturers were sufficiently experienced to make up military clothing, khaki uniforms during the first months of the War were not being turned out in the quantities required by the War Office. The design of the military uniform was therefore simplified. This at once (October) made it possible for many firms whose experience was limited to civilian work to undertake the new military pattern, and within a few weeks the orders for khaki clothing filtered throughout the trade.

Those branches which were best equipped, both by reason of the nature of their previous civilian work, their machinery, and the division of their labour, to manufacture khaki clothing for the New Armies were the wholesale bespoke, ready-made, and medium branches. To a certain extent the slop and shipping branches of the trade were pressed into making the new clothing, though they were better fitted for and chiefly engaged in making up lighter undergarments, belts, shirts, kit-bags, mess-tin covers, canvas bandoliers, haversacks, nosebags, bedding, &c., for Army requirements. The retail bespoke branch was unable economically to produce the new Government clothing even at the comparatively high flat rates which were given for it. Consequently men from the retail bespoke trade entered the wholesale bespoke and ready-made trade as skilled hands, *e.g.*, viewers and foremen, and in those parts of the work requiring physical strength, such as pressing.

The military demand was for clothing that could most economically be made up by power machinery in the factories, and in small workshops, where a highly evolved sub-divisional system made it possible to compete with the factories, the great revival in the trade was only a revival in that part of the *trade which normally employs, outside the cutting rooms, a preponderance of female labour.*

The great increase in women's employment in this trade and the considerable decrease of men's employment which accompanied it should not be interpreted as showing that women have displaced men in the sense that women are now doing processes in the tailoring trade previously done by men. Men's employment has been naturally restricted owing to a diminution of orders in that part of the trade in which men's labour predominated, *i.e.*, the retail bespoke trade. Women's employment has enormously increased owing to an unprecedented demand on that part of the trade in which women normally predominate, *i.e.*, the wholesale bespoke and ready-made branch. The nature of the problem may perhaps be made clearer by a reference to the actual processes involved in making up military uniforms.

The cloth is obtained in rolls and has first to be cut into pattern. This is done by men by means of a band of revolving steel with a knife-edge, known as a band-knife machine. The pieces of cloth are laid one upon another to a depth of 24 to 30 and are cut together. They are then rolled up and stacked away. The work is heavy, entails much stretching and strain, and requires considerable skill. A false movement of the cloth may 'spoil' dozens of suits and mean considerable financial loss. Various rumours and a few instances of women employed as band-knife cutters have occurred, but so far women have displaced men only in the operation of 'laying out' and 'rolling up' of the cloth. A strong exceptional woman might successfully undertake band-knife cutting, but in almost every case the work is unsuitable for women. Women, however, do cutting on lighter cloths and in smaller quantities in the ladies' tailoring part of the trade, though even here it is exceptional. The Trade Unions concerned strongly oppose the introduction of women into the cutting rooms, even where laying out and rolling up (normally done by boys) are the only processes done by them. They have agreed, however, that women shall be engaged on these processes, for the duration of the War only. Women themselves do not seem desirous of undertaking the work.

Fixing and Basting, *i.e.*, placing the pieces in their places ready for the machinist. This is skilled work, and though it is usually done by men there seems no reason why it should not be undertaken by trained women. Basting is often done by women.

Machining, by power or treadle machines, employs more workers than any other process. Save on very heavy work, *e.g.*, overcoats, the process is done by women. In small workshops more women machinists have been employed since the War.

Finishing, *i.e.*, cleaning or taking out cotton tacks and cutting off cotton ends; button-holing (by machine), buttoning (by machine or hand), and 'felling in' pockets, linings, etc., is entirely women's work, and is worse paid than any other process. There is a felling machine on the market, and though it is likely to have an enormous influence later on this branch of women's work (which is partly done by home workers), it has apparently not yet been brought sufficiently to the notice of the trade. The machine costs about 70*l.*, but owing to the present low rates paid to women finishers the incentive to install this machine does not appear to be strong.

Pressing consists of under-pressing of seams and pressing off the whole garment. The seam pressing, which is lighter work than the pressing off, is done by women. On cheap goods a machine press—the Hoffman—is used by a few firms. This press was recently introduced from America and is worked by women. It has probably displaced some men, but is not used to any great extent. Other mechanical presses are also used, but none to any appreciable degree.

To meet the seasonal fluctuations of demand in the tailoring trade the factories depend upon the smaller employers or sub-contractors, and these sub-contractors depend upon other sub-contractors and home workers to assist them in time of excessive activity. There is always a considerable number of small employers and home workers on the fringe of the trade with whom work is placed to be made up during periods when trade is exceptionally brisk. It is difficult to say how large this reserve of labour is, but in London it is a very elastic factor. It consists of people employed in various allied dress trades such as shirt- and dress-making; of married women who wish to supplement the casual earnings of their husbands, and casual home workers; and of small 'slop' tailors

who undertake better-class work when they can get it. As army clothing orders filtered through the tailoring trade, this reserve of labour was quickly absorbed. Employment amongst unskilled workers was exceptionally good, and few women were drawn from this source, but many ladies' tailors, dress- and blouse-makers, as well as charwomen, cigar and cigarette makers, box-makers, shorthand typists and foreign correspondents, book and envelope folders, babies' and women's boot and shoe makers, umbrella makers, and workers in luxury trades generally were attracted to the trade. Any woman who was able to manage a machine could obtain employment. The output was increased by extra overtime, the Home Office allowing relaxation of factory legislation on application by particular firms. To meet the demand, new factories and workshops for the manufacture of khaki clothing were started, and other workshops were converted for the purpose of making the necessary clothing for the Army. Premises engaged in making underclothing, ladies' mantles and costumes, as well as ordinary tailoring workshops, were immediately adapted for the purpose. In one instance, a walking-stick manufacturer suddenly gave up his trade, and a week afterwards was employing a dozen people in making khaki clothing. In another case, a refreshment contractor for weddings gave up his ordinary business and converted his premises into a khaki-clothing factory.

By the middle of February the New Armies had been clothed and contracts were cut down by about 50 per cent. The clause prohibiting sub-contracting was reinserted into War Office (but not Territorial) agreements, and those small sub-contracting workshops which were not taken over by the contractors were soon busy on overdue civilian and shipping orders which had accumulated.

The War Office has decided shortly to return to the original pattern of Army clothing and this will mean a reduction in the number of those firms able to undertake the work. Merchants' stocks of civilian work are, however, depleted, and the shipping trade is brisk, so that the diminution of Government orders or their concentration in fewer firms will probably not cause for some months any appreciable increase of unemployment in the trade. Workers in dress who were absorbed by the tailoring trade will probably still find a demand for their labour in other branches of the clothing trade.

To sum up :

(1) Compared with other trades, the tailoring trade shows a very considerable increase of women's employment, probably an increase of 20,000 or 14 per cent., owing to the placing of Government orders for military clothing.

(2) This increase has occurred in the ready-made, wholesale bespoke and medium branches of the trade in processes such as machining and finishing, which are normally women's work. There has been no appreciable displacement of men by women save in minor operations, *e.g.*, 'laying out' and 'rolling up' in the cutting rooms.

(3) Before the War the limit to which women could be employed in tailoring was practically reached. Men's processes are either too heavy or require more training than the majority of women are prepared to give.

(4) Military tailoring is normally a special branch of the trade. The simplification of the design of military clothing made it possible, however, for firms normally doing only civilian work to undertake the manufacture of khaki clothing. Further facilities were afforded by the relaxation of the clause in agreements prohibiting sub-contracting.

(5) The War Office clothing requirements have now been met, and clothing contracts have been considerably reduced in consequence. Sub-contracting has been prohibited, and it is stated that the original design of the clothing will shortly be revived. This will result in a decrease in the volume of women's employment.

(6) The future of women's employment in the tailoring trade will be affected by the further introduction of machinery. Since the War, small workshops have introduced machinery and power to an unprecedented degree. The use of the Hoffman press, which is worked by women, has displaced men hand-pressers to a limited extent. A felling machine, which would displace women finishers, is on the market, but it has not yet been taken up to any extent by the trade.

CHEMICALS.

	1901 Census			1911 Census			% Increase or Decrease		
	Persons	Males	Females	Persons	Males	Females	Persons	Males	Females
Total Order	128,640	101,938	26,702	177,777	137,572	40,205	+38·2	+35·0	+50·6
Explosives and Cartridges	10,969	6,697	4,272	9,279	5,256	4,023	—	—	—
Chemicals and Alkali	27,220	23,293	3,927	40,562	33,473	7,089	+49·1	+43·7	+80·5
Oil, Grease, Soap, Colours, Dyes, &c.	26,516	21,662	4,854	43,465	35,737	7,728	+34·7	+60·5	+59·3
Lucifer Matches	2,406	541	1,865	2,700	743	1,957	+12·2	+37·0	+5·0

The following figures show the increase or decrease of employment in the trade from the outbreak of war to the middle of February :

Chemical Trades	Net expansion or contraction % in Feb. 1915 of numbers employed in July 1914	
	Males	Females
Heavy Chemicals	+11·0	+ 5·2
Chemicals for Textile Trades, &c.	+14·1	+18·6
Drugs and Fine Chemicals	+12·6	− 1·5
Soap, Colours, Varnish, &c.	+16·7	− 0·9
Explosives	+69·0	−38·1

There has been a steady increase in employment in the Chemical trade from the outbreak of war. The number of women in explosives which in July 1914 was about 8,000 has considerably increased, being drawn from other branches of the trade such as photographic workers and manufacturing chemists where work was comparatively slack largely owing to lack of materials, and from depressed trades such as printing, furniture, and cycle and hardware. The division of male and female labour in the trade seems clearly defined, and there is practically no question of women working on processes previously done by men. In some cases women are being employed in the making of photographic plates.

COTTON.

The following table shows the relative numbers of men and women employed in different processes in the cotton industry :

Cotton	Census 1911		Percentage of Women occupied	Percentage of Men occupied	% Increase of Women in 1901 Census	% Increase of Men in 1901 Census
	Total No. of Females of 10 years and upwards	Total No. of Males of 10 years and upwards				
Card and blowing room processes	55,488	14,695	79·1	20·9		
Spinning processes	55,488	84,079	39·8	60·2		
Winding and Warping	59,171	20,486	74·3	25·7		
Weaving	190,922	82,341	69·9	30·1		
Other processes	10,768	31,779	25·3	74·7		
Cotton—all processes	371,797	233,380	61·4	38·6	+11·9	+18·5

During the first four months of the War, this industry was the most depressed of all trades, and in regarding unemployment figures as a whole this fact should be noted. Before the War, production had over-reached demand, and, in addition, at the outbreak of war the trade suffered from the disadvantages resulting from the War under which all export trade laboured—high rates for freight and insurance; the prohibition of code telegrams; and, during August, the dislocation of the machinery of bills of exchange; as well as the loss of German markets.[17]

The seriousness of unemployment in the cotton trade is not merely to be seen in the figures of unemployment, for in textile industries as in mining a contraction in the demand for labour is more generally met by a reduction in the time worked per week by a large number of workpeople than by the discharge of a smaller number. The following table traces the changes in the cotton trade from the outbreak of war to the middle of February:

(Number employed in July=100)

Males.

Month	On Short Time	On Overtime	Contraction of Employment	Known to have joined the Forces	Net Displacement (−) or Replacement (+)
	%	%	%	%	%
September 1914 . .	43·5	0·1	17·2	4·3	−12·9
October ,, . .	40·5	0·4	17·1	6·8	−10·3
November ,, . .	42·1	0·9	14·8	8 3	− 6·5
December ,, . .	30·4	1·6	13·3	9 6	− 3·7
February 1915 . .	11·2	2·2	11·1	11·6	+ 0·5

Females.

Month	On Short Time	On Overtime	Contraction of Employment
	%	%	%
September 1914	44·6	0·2	14·9
October ,, ...	44·2	0·5	14·0
November ,, ...	46·2	0·9	11·5
December ,, ...	34 0	0·8	9 3
February 1915	15·5	0·9	3·0

The general improvement in December was due partly to recovery of trade with the East, but in the main to the increase in the number of Government orders placed in Lancashire. To a very large extent these orders involved the substitution of coarser for finer yarn, a change which involved some adjustment in wages and working conditions.

From many cotton towns a shortage of male labour was reported, especially of piecers and of various classes of labour in the winding rooms. Spinners manipulate a pair of machines and require the aid of two operators—big piecers (men earning up to 26*s.* per week) and little piecers (boys). Before the War a serious shortage of little piecers was being felt as boys now take less kindly to mill life. Now the problem is complicated by the dearth of 'big piecers' who have enlisted for the War. The employment of women as piecers is a most controversial topic, and though a certain number of women are normally employed in some districts, generally in colliery districts when youths are not available or in rural districts, and attempts have been made since the War to introduce young women and girls to assist in creeling, there is a strong

[17] For further information on the War and the Cotton Trade see article by Prof. S. J. Chapman and D. Kemp in *Economic Journal*, March 1915.

feeling on the part of the men against their employment—mainly on the ground that women are not so physically strong as men, and cannot do much of the work performed by a male piecer, and that they would tend to undercut men's wages. Substitution has, however, taken place, *e.g.*, in Bolton alone the number of women piecers has risen since the war from about 20 to 300. All are members of the Spinners Union. The number of piecers has also risen in Manchester.

The point of view of the woman is not necessarily that of the man, and a prominent woman Trade-Union organiser of women in Lancashire who is secretary to a Lancashire Trade and Labour Council sees no objection to women being employed as piecers save the artificial restriction which prohibits a woman from becoming a spinner. A few women have, however, for years been employed as 'spinners' at Lostock Junction, Lancs, at lower rates than the men. Efforts are being made both by the Board of Trade and the Local Government Board to induce the Operative Spinners' Union to consent to the employment of women in spinning mills. The membership of the Spinners' Amalgamation includes 1,500 women as partial members. The objections by the men to the introduction of women as spinners are stated to be :

(*a*) The probable undercutting of the wage rates paid to men spinners.

(*b*) The conditions of the work when men and women work together are objectionable morally.

(*c*) Women's dress is unsuitable among swiftly moving machinery.

One Trade-Union official was of opinion that 'the stoppage of the mills would be preferable to going back to the days of fifty years ago when women's labour was not at all uncommon in the spinning rooms. The work is no more suitable for women than coal-mining.'

Weaving is done both by men and women, who are paid the same piece-rates, and do the same work, except that

(*a*) men work the wider machines (quilts, &c.)

(*b*) men more often work 6 instead of 4 looms.

(*c*) men are able to set their own machines, hence they lose less time than the women.

(*d*) women do not rise to be overlookers.

The tendency is for the number of men weavers to decrease. Men prefer spinning and other better-paid trades. As trade has been very slack since the War the need for introducing more women in weaving has not arisen.

Women and men warpers are paid at the same piece-work rates, but men generally work two machines, while women work 1 or 1½, *i.e.*, two women to three machines.

Both men and women are employed as twisters and drawers, and they work on the same piece rates. The women earn from 45*s.* to 60*s.*, out of which they pay the wages of a reacher, about 10*s.* Women also pay the men to lift heavy beams, although the men sometimes help the women for nothing. Women are never employed as beamers, the work is too heavy, and the men would object. The number of women twisters and drawers are being slightly increased as the result of the War.

Women are normally employed in the warehouse section of dyeing and bleaching, in cutting up lengths, silking, ribboning, and folding light materials. Men normally fold the heavier materials and work the lapping machines. The rates of pay vary between time rates—good 16*s.* to 17*s.*, low 12*s.* to 13*s.*, and piece rates 20*s.* to 25*s.* The Union tries to enforce a minimum of 18*s.* for women, but this is no more than an aspiration, the agreed scale of wages in 1912 for girls of fourteen to eighteen years of age being 5*s.* to 12*s.*, in other cases 10*s.* as a maximum.

Women have also taken men's places in dyeing-machine minding. Women are not normally engaged at all in the dyeing or bleaching departments, as the work is said (by the men) to be too dirty for women. The Trade-Union rule with regard to women's employment in this process is being relaxed, conditional on women being paid the same rate as the men.

Since the War, women have been introduced in some cases as lapping-machine minders, work which is normally done by men. Though stated by the

men to be work too heavy for women, it could probably be done quite well by them. The men's Trade Union, however, will probably allow the employment of women on this process, provided that they are paid at the same rates as the men.

During the last forty years there has been a tendency for the number of men among card-room operators to decrease in proportion to the women, the number of males in the trade being practically reduced to a minimum. The men's work, however, has not been taken by women, but a woman's process has displaced a man's process.

Ring-spinners are mainly women, though a few male ring-spinners are employed to do night work. Competition is increasing between female ring-spinners and male mule-spinners. The women earn from 15*s*. to 32*s*. per week, and the men from 30*s*. to 70*s*.

Since the War, a proposal was made by a certain employer to the Trade Union that three women earning 15*s*. a week each should be allowed to take the place of two men earning 32*s*. a week each who had enlisted for service, the women to do the lighter part of the work only, while the heavier part was to be transferred to the men. The proposal was unanimously rejected by the Union according to its usual practice of resisting strongly the employment of women on the lighter parts of men's work at lower rates, while the men are left with the heavier parts and no increase of pay.

In the cotton dyeing and finishing branch of the trade women are excluded normally from all wet processes, and there has been no relaxation of Trade Union rules since the War. In the calico printing trade, women have replaced men, but in no other process There is some evidence of male and female competition in cotton polishing.

Wool and Worsted.

The following are the numbers employed in the trade according to the Census of 1911 :

Wool and Worsted	Males	Females	Increase on 1901	Increase on 1901
			Males	Females
Spinning processes	25,391	45,310		
Weaving processes	24,419	67,499		
Other processes	29,854	8,101		
Total	79,664	120,910	9·0 %	4·2 %
Wool-sorting, carding, combing . .	15,867	6,238		

The trade has been considerably affected since the War by large Government orders for khaki and other cloth. The war boom is now, however, less than it was in the winter and spring, but an accumulation of overdue orders for civilian purposes has kept the trade brisk in spite of the reduction in the Government demand. The number of women employed has increased since the War, and especially during the month of December, when the Government demand was at its zenith, but the extra women employed have rather come into the trade to take up new work than to replace men. A shortage of dyes has from time to time hindered production in the trade.

Employers are now (August) finding increasing difficulty in obtaining either male or female labour, and in a number of cases are training and bringing new women into the trade. They complain of the difficulty, owing to separation allowances and billeting, of persuading married and other women to return.

The distinction between 'woollen' and 'worsted' is of primary importance in this trade. Broadly, the difference is one of locality as well as quality of wool. The worsted trade is practically confined to the west of the West Riding of Yorkshire, where, by processes including 'combing,' which are carried on generally in separate mills, the long wool is spun and woven into fine cloth.

Bradford, Huddersfield, and Halifax are the chief centres of this trade. The woollen trade is carried on to the eastern part of the West Riding, with Leeds as the chief centre. Here the short wool undergoes several processes, including carding, in the same mill. The distinctions between the long and the short wool, however, are breaking down with the introduction of improved machinery, which enables short wool to be combed as well as the long wool. The fundamental distinction is that in the worsted the wool is combed so as to lie in horizontal line, while in the woollen it is carded to present a felted appearance.

Men and women *weavers* are normally employed on the same processes, save that

(*a*) men do night work;

(*b*) men are able to 'tune' their own machines and do small repairs, and so save time and the expense of a mechanic;

(*c*) men are generally employed on the better-class and better paid work.

Men weavers are mainly confined to the Huddersfield district, where fine 'suitings' are made, as against 'dress materials' in Bradford, and 'tweeds' in the Leeds or 'heavy woollens' district. Outside the Huddersfield district, weaving, save in plush weaving and certain better-class branches of the trade, is a woman's trade. In slack times the men on night work are the first to suffer from unemployment, and are not infrequently supported by their wives on day work.

Both females and males are normally employed in the Huddersfield district as winders, warpers, and *condenser minders*. Boys as well as women are employed as winders. In Scotland (Tweed district) boys are sometimes employed as condenser minders, but in Yorkshire this work is generally done by men or women.

There are two separate piece-work rates for men and women weavers in Huddersfield—the men earning an average wage of 27*s*., the women 18*s*. In Bradford and Leeds men and women are generally employed at the same piece-work rates, but no wages scale has been fixed as in Huddersfield, while the average is lower than in Huddersfield. On 'khaki' work women may earn up to 27*s*. a week or as much as an average man. A number of married women have since the War returned to weaving, but, as the practice is for women to return to the trade under their maiden name, no exact information on this point is available. There is always a reserve of married women 'jobbers' or 'casuals' in the trade who come in in times of pressure.

Where men and women are employed as machine woolcombers on the same processes, either

(*a*) men do night work and the women day work, as in the case of 'comb minders,' 'strong boxminders,' or 'furnishing boxminders'; or

(*b*) the women work lighter machines, as in the case of 'breakers off'—women 2 laps, men 4 laps; or

(*c*) the process itself is somewhat different, as in the carding department, where men or youths feed the machines on the 'hopper' principle (bowl feeders), while women feed the machines on the easier 'feed-board' system There is little doubt that women could, and would, long ago have been employed as 'bowl feeders' on the 'hopper' principle, were it not for the opposition, or as some would have it 'the chivalry,' of the men on the ground of the unsuitability of the work for women.

Where men and women do exactly the same work, day work and night work, a capable woman will sometimes turn out more than a man, but the men have, as a rule, the larger output. There is no doubt, however, that the lower wages of the women are out of proportion to their lesser output. There appear to be no cases in this branch of the trade of women taking men's work since the War.

Some women weavers have come in attracted by the higher wages in woolcombing. Attempts were made in the early months of the War to put women on night work, but the men then successfully resisted this on the ground that there were sufficient semi- or unskilled men who could be drawn from other trades or be promoted in the woollen trade to meet this temporary demand. The men say they do not object to the introduction of women labour, provided

that there is a shortage of male labour and that the women are paid the same rates as the men displaced. By this time, however, the shortage both of male and female labour is very obvious.

Hosiery.

Since the War the hosiery trade has been steadily and more than usually busy, and the employment of women has considerably increased. For some years the number of women drawn into the trade has been proportionately larger than that of the men, whose numbers have slightly decreased, as the following figures show :

——	Males	Females
1881	18,862	21,510
1891	18,200 (—3 5)	30,887 (+43 6)
1901	13,893 (—23·7)	34,481 (+11·6)
1911	14,957 (+7·5)	41,431 (+20·2)

The men in the trade are mostly elderly, and there has been no displacement of men by women. Considerable efforts are being made to capture German trade, and employers are laying down more plant.

(*a*) Small machines of the Griswold type on which women are employed.
(*b*) Large machines of the Cotton's type on which men are employed.

Trade is very brisk, large Government orders having been placed for pants and vests, which are being made on Cotton's machines (men's process), and for socks, which are being made in huge quantities by women on seamless machines. There is a shortage of women in the trade, especially in the rural districts, although they have been drawn in in large numbers, particularly in the East Midlands from the lace trade. Belgian refugees have also found employment in this trade. Old men are being employed as winders. In London, women from depressed trades, such as Court dressmaking, have been successfully employed by the Central Committee for Women's Employment in making socks.

Silk Trade.

The following figures show the percentage decrease in this trade of male and female labour over the ten years 1901 to 1911 :

Census 1901			Census 1911			Increase or Decrease per cent.		
Persons	Males	Females	Persons	Males	Females	Persons	Males	Females
34,847	10,380	24,467	29,643	9,087	20,556	—14·9	—12·5	—16·0

It will be seen that of recent years the silk trade has been a declining one.

At the end of the first six months of war the contraction of the number of women employed was 3·4 per cent. of the number employed in the previous July. The number of men recruited was 13·7 per cent., and the contraction in male employment was 8 per cent., leaving places to the extent of 5·7 per cent. of the total number of men employed in July to be filled.

Women are normally employed as *Winders*, *Coppers*, *Denters*, and *Spoolers*. They are employed in *Weaving* in places outside Leek, and the employment of women weavers is increasing in towns like Cheadle, Derby, Prestwich, Macclesfield, Manchester, and Nuneaton. The men's union in Leek has made it impossible to employ women in that town, with the consequence that the silk-weaving industry, save the very high-class trade, which employs only about 120 men, has almost entirely disappeared from Leek. Since the War the Leek men's Union has financed the organisation of the women weavers outside Leek into a Trade Union.

The women weavers' piece rates are generally about one-half that of the men's and they earn from 12*s*. to 14*s*. a week, as compared to the men's 30*s*. It is stated that

(*a*) The women need more supervision than the men.

(*b*) They require the assistance of a loom 'tackler.' One tackler generally attends 30 to 40 women, and his wages are 30*s*. per week. In Cheadle four tacklers are employed to 300 women.

Since the War the employment of women has largely increased in the net silk, spooling, and the artificial silk fabric branches of the trade, where women normally predominate. There has been a certain acceleration of displacement of men weavers by women. When this has taken place the men have asked that the women shall receive the same wage rates as the men. At present no women have been introduced to processes which have been hitherto performed by men only. Since the War the men but not the women weavers have received a war bonus of 7½ per cent.

Braiding, Tie and Scarf Knitting.

Both men and women are employed as Braid Tenters. They do the same work save that

1. Women mind 1 to 5 large machines and they are also assisted by a 'tackler.'
2. Men mind 30 to 60 small machines and sometimes 2 or 3 larger machines as well.

The men are paid on piece-work rates and the women on time rates, the men earning 30*s*. to 32*s*. a week, and the women about 16*s*. a week (Trade-Union rate). It is said that the men prefer to keep the women on time work as they fear to be ousted by women on piece work! Since the War a number of women braid tenters have displaced men, but they still receive the women's rates of pay and not the men's, with 1*s*. extra as War bonus.

On scarf and tie knitting men and women are employed at the same piece-work rates, but the men have the larger output. Women mind 2 to 4 machines, and also require the assistance of a 'tackler.' Men mind 6 to 8 machines unassisted. Men are also employed on night work, for which they are paid at a rate and a half. Women, however, are increasingly employed on these processes. Since the War women have also been employed as overlookers.

FOOD TRADES.

The following table shows the increase (per cent.) from 1901 to 1911 of men and women employed in branches of the food trades most affecting women's labour :

Food Trades	Census 1901		Census 1911		Increase per cent.	
	Males	Females	Males	Females	Males	Females
Jam, Preserve, Sweet makers	6,232	15,899	9,332	20,058	49·7	26·1
Chocolate, Cocoa Makers	2,381	5,220	5,368	12,508	125·5	140·0
Mustard, Vinegar, Pickle Makers	2,006	2,184	3,659	3.522	82 4	61·2
Bread and Biscuit Makers	71,775	4,974	78,730	9,887	43·7	100·0
Grain Millers . .	22,830	775	23,739	1,742	4·0	124·7
Fish Curers . .	2,255	608	3,051	1,451	35·3	138·6
Provision Curers .	3,523	364	1,264	561	122·5	54·1

From these figures it is evident that of recent years the proportion of women employed in grain milling, chocolate making, bread and biscuit making, and

fish curing has increased relatively to the number of men employed. Since the War the grain milling and meat preserving sections of the trade have been especially busy, though in the earlier weeks of the War there was a general depression throughout the trade. The preparation and making up of rations for the troops have led to a considerable increase of female labour in the preserving section of the trade, which normally employs a considerable proportion of women. It is a common practice in the trade for the factories to include tin making and paper-bag making departments. The above figures, however, do not include such extra workers, who really belong to another craft, though the state of their employment naturally depends upon the state of this particular trade. The amount of displacement of men by women throughout the industry has been very limited, though it has occurred in certain processes where men were unobtainable, but much of the work is heavy work, and it is doubtful whether it is work in which women can permanently be retained.

Sugar Confectionery, Fruit Preserving, Chocolate Making, Pickling, &c.

This trade was subject in the early months of the War to a very considerable shortage in raw material—sugar. The Government, however, came to its rescue, and bought up large supplies, and the trade began to revive in spite of the prohibition of the export of certain of its products. The trade employs a great number of women, who are normally engaged in such processes as picking, cutting, and preparing fruit and pickles. They also handle the machines for weighing and packing tea, coffee, cocoa, confectionery and corn-flour, besides attending the stamping and cutting machines in the tin-making department.

The trade employs a large proportion of strong and somewhat rough type of women, and though the men's work is heavy a few of the women have since the War been employed on men's work, *e.g.*, in boiling sugar and peel, making sweets, loading and unloading the goods-lifts with tins, and carrying cardboard for packing.

Boiling sugar and peel is a very arduous task and the heat is excessive—so much so that the women are frequently known to faint. Only the strongest women undertake this work. The wages are low, and the women receive on this process 13*s.* to 13*s.* 9*d.* per week, with sometimes a bonus of 1*s.* or 2*s.* For the same work the men receive up to 26*s.*, though their output is considerably more than the women's, though probably not as much as the discrepancy in the wages. There is a shortage of skilled male labour, especially in the chocolate branches of the trade. The demand for goods requiring a good deal of women's labour in preparing and packing has been largely displaced by a demand for bulk goods for the Front, in the preparation of which a larger number of men are employed than in the ordinary trade. Where men are unavailable women have been employed, but, although in one large factory at least the results are said to be satisfactory, employers as a whole do not favour this course, as the work is heavy and unsuitable for the majority of women. Women and strong girls have, however, largely taken the place of boys and youths, and they are generally employed at the same wage rates as the youths they have displaced on the following processes :

Feeding machines with slabs of sugar.
Shaking down sugar.
Papering cans.

It has been found, however, that more girls and young women are required than youths—sometimes three women to two boys and sometimes two women to one boy.

In this trade wages are low, and though the work is heavy it is not very skilled and depends very largely upon a fringe of casual male workers from other trades. There is therefore little likelihood of the women being retained after the war.

Bread and Biscuit Making.

For some months there has been a shortage of skilled men in bread making, and the scarcity of male labour has made it impossible to employ some women who would otherwise have been employed. A few women from laundries and

the dress-making trades have, however, been drawn into the trade as bakers. In this work two women are generally required to do the work of one man, and the women receive in some cases three-quarters of a man's wages. The women find the heat excessive and require more time off than the men in consequence —generally half an hour in every four hours. Women are, however, being increasingly employed in baking 'fancy' cakes and pastries.

In flour mills a few women have been employed instead of boys as attendants to power machines, and women have replaced men to a certain extent in breweries in bottling and labelling, and in aerated-water factories.

Tobacco.

The following show the increase or decrease of employment in the tobacco trade between the years 1901 and 1911 :

1901		1911		Increase or Decrease per cent.	
Males	Females	Males	Females	Males	Females
7,524	19,972	7,886	19,312	+4·8	−3·3

At the beginning of the War the tobacco trade was not appreciably affected, but by October considerable unemployment occurred, especially in the cigar trade. By the month of February there was an increase in the number of women employed in July of the previous year of 5·2 per cent., and from that time onwards the trade has been extremely busy. Before the War the trade was subject to considerable fluctuations, and there was a large surplus of male labour, chiefly foreign, which has been absorbed since. Replacement of men by women has taken place to a very slight extent, though women and girls in many firms have taken the place of boys, mostly in blind-alley occupations, and will probably be retained after.

Just before Christmas, owing to the large consignments of cigarettes and tobacco sent to the troops, a considerable boom took place, mainly in the cigarette branch of the trade, and this part of the trade has been increasingly busy since, owing to large War Office and private orders.

Besides cigarette making proper a considerable part of the cigarette trade consists of box-making, soldering, labelling, packing, and dispatching, in which a large amount of female and boy labour is employed. Since the war boys have almost entirely been replaced by girls. In the actual processes of making cigarettes the line between men's and women's work is clearly defined. The men are engaged on the heavier work, such as handling the hogsheads of leaves, unpacking and cutting the leaves, and on work requiring skill, such as pan-work. Male mechanics also attend to the cigarette machines. Girls and women are employed in stripping the leaves and in feeding the cigarette machines and catching and examining the finished cigarettes. They solder tins and do every process save the handling of heavy cases in packing, wrapping, and dispatching. Women also make cigarettes by hand, though men make the better class "flat" cigarettes. Since the War, however, the great increase in demand has been for machine-made cigarettes.

Brush Making.

According to the 1911 Census there are 9,813 males and 7,702 females employed in this trade. Since 1901 the increase in the numbers of women in the trade was 10 per cent. and of men 6 per cent. Since the War employment in the trade has been fluctuating but on the whole good. Before the War, a German kartel had succeeded in substantially monopolising the source of the bass supply, and the trade in England was declining, but since the War the supply has again been secured. Health Insurance records show that married women and others who had ceased to be employed before the War have

returned to the trade. The industry has been seriously handicapped since the War by the shortage of skilled men—the women in the trade being for the most part unskilled.

In Trade-Union shops women are employed only on brush drawing, the Trade Union objecting to their employment on other processes on the ground that it would tend to lower wages. None of the Unions appear to admit women to membership.

In the process known as panwork, *i.e.*, the fastening of the hair and fibre into the stock of the brush by means of a mixture consisting largely of pitch, women previously worked fibre only, but since the War they have worked in both fibre and hair. In some cases, however, women now do this pan-work on Army hair-brooms. The women cannot, however, finish the process entirely. The work is 'trimmed off' by men, the women boring the holes and 'knotting' and 'fixing' in the bristles. Some instances have occurred where women do the 'knotting' and 'trimming' themselves.

Printing and Bookbinding.

This trade was investigated by Miss E. Ashford. The following table shows the increase or decrease of persons engaged in the printing and bookbinding trades in England and Wales during the period 1901 and 1911.

It will be seen from the table opposite that the entry of women into the printing trade has for some years been a normal feature of the trade and that their numbers have rapidly increased in a much greater proportion than those of the men. In the bookbinding trade, on the other hand, there has been a diminution of women's employment and an increase of the employment of men.

The absence of particulars given in the 1901 Census makes it impossible to correctly estimate where the increase of women's labour has taken place. The small number of women, however, in all grades of printers except 'others' make it extremely probable that the increase is not in the processes usually done by men, but among 'folders,' &c., who are usually women and would be included under 'others.' The large increase in lithographers is proportional rather than numerical and would refer chiefly to the 'feeders.'

Although not all branches of the trade have been equally affected by the War, this industry, as a whole, has suffered as severely as any, and in view of the fact that they are in no sense war material, some branches may for the duration of the War practically be classed among the 'luxury' trades. A general depression was felt almost immediately on the outbreak of war and short time became general, but especially in the bookbinding trade. This depression lasted through August and September, the exports for these months being only 76 and 79 per cent. of the figures for the corresponding months in 1913. Government orders, however, for the printing of banknotes, mobilisation orders, and various handbills and instructions to troops, did something to relieve the depression in the first months. From this point an improvement set in, the shortage of paper, which at first was stated to be an important factor in the trade depression, and especially in newspaper printing, was being readjusted, and at Christmas time something like the usual seasonal revival took place. Compositors, however, continued throughout to suffer severely, and there is no doubt that unemployment, or short-time employment, has been responsible for much of the enlistment from the printing trade. That, and the transference of workers (especially bookbinders) to other industries, appear to have balanced almost exactly the contraction of employment in the trade, and the month of July has been the best month since the outbreak of war. Unless, however, the drain of enlistment upon the supply of labour becomes excessive, there can be no question of the importation of women into the trade in large numbers, as there is no prospect of any considerable revival during the War. There is, therefore, a twofold reason why no change in the position of women in the printing trade is likely at the present time :

(1) The heavy, difficult, and unhealthy character of much of the work

	Census of 1901			Census of 1911			Increase or Decrease per cent.		
	Persons	Males	Females	Persons	Males	Females	Persons	Males	Females
Total of Printers, Lithographers, Bookbinders .	149,793	119,834	29,959	184,075	140,968	43,107	+22·9	+17·6	+ 43·9
Printers:									
Hand Compositors	106,181	96,488	9,693	37,883	37,281	602	+29·6	+19·5	+130·8
Machine Compositors				3,803	3,711	92			
Printing-Machine Minders				7,982	7,773	209			
Stereotypers, Electrotypers				2,771	2,761	10			
Others in Printing (including undefined) .				85,198	63,736	21,462			
				137,637	115,262	22,375			
Lithographers, Copper, and Steel Plate Printers .	11,725	10,682	1,043	15,029	12,746	2,283	+28 1	+19·3	+118·9
Bookbinders	31,887	12,664	19,223	31,409	12,960	18,449	− 1·5	+ 2·3	− 4·9

and the complicated nature of the machinery, make the employment of women impracticable, except in the capacity of subordinate workers.

(2) The supply of labour is at present adequate to the demand, and likely to remain so for some time to come.

That women are useful mainly in subordinate capacities may be inferred from the information supplied by the census figures. The printing trade, as far as women are concerned, is shown to be essentially a young person's trade. Thus the numbers employed between the ages of 15 and 25 years are not far short of 4 times the numbers employed between the ages of 25 and 35, while the number of girls of 13 and 14 years employed alone exceeds by nearly 1,000 the total of women employed between the ages of 35 and 45. The greatest numbers are employed between the ages of 15 and 18 years, from which point a fairly rapid decline begins, those employed at 19 and 20 years being respectively 8·4 and 9·0 per cent. less than those of the preceding year. And the total employed between the ages of 20 to 25 is only 28,935, as compared with 41,653 between 15 and 20 years.

These figures indicate that up to the present the printing trades have little prospects for women, and that they are, in fact, most employable as adolescents, and, as stated above, in subordinate capacities. At present the employment of women in the trade is in a transitional and uncertain state. As compositors, for instance, their position in the Edinburgh printing trade is to be considered anew in 1916. The employers' view, speaking generally, is that men are on the whole to be preferred to women in nearly every branch of the trade, and the employment of women is favoured only on account of their lower rates of pay, or, as one Trade Unionist expresses it, 'their greater docility.'

This is one of the chief objections urged by the Trade Unions (who, on the whole, would like to see women out of the trade altogether), that the lower scale of women's pay tends to depress the standard of wages in the whole trade. Their other objections are :

(I.) The strenuous and unsuitable character of much of the work, from which follows as an almost inevitable consequence :

(II.) The clear-cut division of labour into unskilled, done by women, and skilled, done by men, which, they fear, may lead ultimately to an overcrowding of the trade with skilled journeymen.

As already indicated, the effect of the War on the trade is mainly one of depression and only in isolated instances are women doing work new to them or being employed in larger numbers in their own processes.

Processes in which women are doing work which before the War was done by men :

(1) *Feeding (Cylinder or Rotary Machines).*

To a limited extent women are taking the place of men as layers-on on cylinder or rotary machines. The unsuitable conditions in which the work is done and its strenuous character have hitherto prevented the employment of women. The process is easily learnt, however, and is being entered in increasing numbers. Employers state that their work is, on the whole, as good as men's, but more labour is thrown upon the minder, who has to carry the heavy weights for the women. Or a labourer is employed, one to three or four women, to do the heavy work. An arrangement has been made by which the women are to do the work for the duration of the War for 23*s.*, instead of the men's wage of 25*s.*, in view of the labourer's services being required.

Non-union women are being employed at 16*s.* a week.

(2) *Folding and Inserting (heavier work).*

A few women are being employed in the heavier part of the work, normally done by men, especially for the feeding of the smaller folding machines. This is piece-work, and a woman will earn up to 25*s.* with experience.. Overtime rates differ from those paid to men, women receiving 6*d.* an hour instead of 10*d.*

(3) *Unpacking, Sorting, and Returning Newspapers.*

Women are being supplied by the unions for this work, at 20*s.* instead of the men's rate of 25*s.*, as a man must be engaged to lift heavy parcels for them.

(4) *Bookbinding.*

Women are at present doing work which is usually done by men, mainly in pasting the joints and in flush binding generally; also in some of the easier parts of vellum binding, which, as a process, is highly skilled and has hitherto been entirely in men's hands.

Processes in which women are normally employed :

(I.) *Feeding.*

The employment of women has been increasing for a considerable time. The work is unskilled and the reason sometimes given for employing girls instead of boys is that if boys are employed, it brings too many into the trade. A considerable number of boys, it is true, enter the trade as feeders and have to leave it at the age of eighteen. The work is low-paid, as a rule, starting at 5*s.* and rising to 10*s.* or 12*s.*, but in a good firm, after four or five years' experience, a girl will get as much as 15*s.* or 16*s.* The low rate of pay prevailing is due to the fact that girls cannot set on the machines themselves, as boys do, but require a boy, or, more usually, a man supervisor. Before the War, self-feeding machines were coming into use, which would ultimately do away with girl labour; but the difficulty of getting the machines has temporarily checked this movement.

In lithography feeding there is a tendency just now to employ women in increased numbers and take on girls where men were employed before. The work needs little training and is poorly paid, 5*s.* rising to 10*s.* or 12*s.*, but is done generally in more healthy surroundings than other processes of the trade.

(II.) *Folding and Inserting (lighter work).*

This has always been women's work and the number employed is still increasing. The wage is about 17*s.*, as compared with 30*s.* and upwards paid to men, who do the heavier work of gathering and sorting, and night work as well.

(III.) *Machine-ruling.*

The number of women is increasing, largely because the setting of the pens, which hitherto has been the chief obstacle, has become a comparatively simple process since the introduction of the latest machine. Men and women do the same work as minders, but the employment of women is opposed and they are not admitted to the Machine Rulers' Union. The Machine Rulers' Union in Manchester prohibits the employment of women both in machine minding and ruling. The National Operative Printers' Union, however, accepts them as minders, fixing their minimum rate at 15*s.*, men's 36*s.* Women earn 15*s.* to 18*s.* The War has had no marked effect on employment in this process.

(IV.) *Reading.*

For some time past there has been a tendency to substitute girls for boys and it is likely to continue. The change is desirable, as the work is to some extent a blind-alley occupation for quick boys, who can earn up to 18*s.* but get no further unless they get into the newspaper trade, where, however, they cannot rise beyond 32*s.* 6*d.* In view of the fact that women are for the most part employed for a period of years only in the printing trade, this substitution of girls for boys is in accordance with the general attitude towards the employment of women in the trade.

Wages for girls and boys are the same.

(V.) *Composing.*

There is a strong inclination on the part of trade unions and of some employers to keep women out of this branch altogether. The work is highly skilled, and the apprenticeship a long one, except in the case of hand composing in book printing, which requires less judgment and experience, and it is in this branch of the trade that women are chiefly employed, to a small extent in London and in larger numbers in the provinces. The work is strenuous and carried on in a close atmosphere and involves the lifting of heavy weights. For this reason it is generally necessary to have one man overlooking and lifting for two or three women. Women can, however, be advantageously employed in the first process of monotyping, which is done seated and is less tiring altogether. At present, however, monotyping machines are not extensively used, being estimated at about 3 per cent. only of the whole trade. The output of women on monotypes is often as much as a man's, and women joining the union in London must receive a minimum of 45*s.* a week. Outside the union the average is 32*s.* 6*d.* The employment of women as compositors varies in different parts of the country. In many places the opposition of the men is strong enough to keep them out of the process. In Edinburgh, where a number of women are employed on monotyping machines, the whole question is to be reconsidered in 1916.

(VI.) *Bookbinding.*

Certain branches of the trade have been considerably depressed through the War. There has, however, been some increase in the employment of women. Certain processes are prohibited to women in some districts, but conditions vary, and the restrictions are, generally speaking, purely arbitrary. The disputed processes are :

(i.) Drawing on and gluing cloth covers (paper covers allowed).
(ii.) Quarter-binding where the edges are turned in (flush edges allowed).
(iii.) Pasting on end papers. All are very simple processes.

Trade union minimum for women 15*s.*; men 36*s.* Men generally take on other work as well as quarter-binding, whereas women are employed on quarter-binding alone, earning 15*s.* to 18*s.*

The Future.

Reports all agree that the condition of trade after the War will determine this. Men will be reinstated in their old positions, as far as possible, but employers seem, on the whole, inclined to keep on the women introduced since the War, if the condition of trade enables them. Had the trade remained very prosperous during the War, it is more than probable that temporary concessions would have been made by the unions other than those already mentioned in respect of the employment of women. But the unions, generally speaking, are strong enough to be able to enforce a return to the *status quo* after the War, and, whatever changes may take place in the demand and supply of labour in the next twelve months, it is certain that no important changes would be countenanced as a permanent feature without the fullest consideration on the part of the unions. Important changes, however, as already stated, are rendered improbable by the very nature of the printing trade, where a great deal of the work is beyond the physical powers of women, and generally the readjustments which have been made to facilitate the employment of women in the heavier branches of the trade are to be regarded as a temporary expedient and not as a permanency.

At present the great majority of the 12,380 women described in the Census as 'others in the printing trade' (of whom no less than 10,600 are between the ages of 14 and 19) are employed in the purely subordinate occupations as feeders, folders, messengers, &c., and the length of apprenticeship required, in order to qualify women for the more technical and skilled work, which is fixed at a minimum of four years, generally bars the way to any attempt at entering the more skilled branches. In certain directions, however, women may in the near

future be more advantageously employed, as letterpress feeders, as monotype workers, and in certain of the bookbinding processes hitherto reserved to men.

There has been some attempt to investigate the conditions of German work to discover whether the inclusion of more women would enable printers in England to take some of the work formerly done in Germany. There appears to be most opportunity in processes connected with lithography. The point is discussed in a paper on 'British Lithography in 1915' read before the Royal Society of Arts on Feb. 18th, 1915, by Mr. F. Vincent Brooks. The following is a quotation from the paper:

'The second point of vantage that the foreigner possesses is the much less cost, and, I must confess, the much better character of his transferring, and this transferring is a very important item in the total cost. The total volume of this work done in a German factory is very large, so that it is much cheapened by subdivision; a workman is constantly employed filling the barest possible transfers, so bare that the solids generally have to be filled in on the stone or plate; the work is carried out by quite an army of girls, other girls having previously cut up the transfers on the backing that is the full size of the sheet to be printed. This is work for which women are exceptionally well suited, but such employment would be contrary to general usage in this country, and, I imagine, would meet with sturdy opposition from the trade unions; and unless working arrangements of the cost can be made, the British printer will be hopelessly out of it, both with regard to the cost and general efficiency.'

Some comment has been made on the fact that most German factories have been built lately, with a maximum of light and air and are therefore suitable for the employment of women, while those in England are often very old and unsuitable.

Board of Trade, Earnings and Hours Enquiry, 1906.

Based on returns from 110,129 employees.

Men (over 20)	45·6 per cent.
Lads and Boys and Apprentices (under 20)	17·4 ,,
Women	24·2 ,,
Girls (under 18)	12·8 ,,

Average Earnings of above.

Trade	Men	Lads and Boys	Women	Girls
	s. *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*
Paper	29 0	10 8	11 11	7 6
Printing	36 10	8 7	12 3	6 4
Bookbinding	34 1	8 8	12 10	6 6
Paper stationery	31 4	8 6	11 11	6 6
Cardboard and boxes	28 10	10 3	12 3	6 1
Wall paper	32 11	19 2	13 2	7 9
Process block making	45 9	9 7	18 9	9 5

Percentage of Wages. Working full time.

Men.

Under 12*s.* 0*d.*	·1 per cent.		
s. *d.* *s.* *d.*		*s.* *d.* *s.* *d.*	
12 0 to 15 0	·5 ,,	40 0 to 45 0	9·7 per cent.
15 0 to 20 0	6 2 ,,	45 0 to 50 0	5 ,,
20 0 to 25 0	15·2 ,,	50 0 to 55 0	3 ,,
25 0 to 30 0	14·5 ,,	55 0 to 60 0	1·6 ,,
30 0 to 35 0	20·9 ,,	60 0 to 65 0	1·8 ,,
35 0 to 40 0	17·9 ,,	Over 65*s.*	3·6 ,,

Percentage of Wages. Working full time—continued.

—	Boys	Women	Girls
s. d. *s. d.*	Per cent.	Per cent.	Per cent.
Under 3 0 . .	·5	0	1·3
3 0 to 5 0 . .	8·4	·7	24·4
5 0 to 10 0 . .	54·9	25·8	64·0
10 0 to 15 0 . .	26·0	52·2	8·6
15 0 to 20 0 . .	8·9	16·5	·6
20 0 to 25 0 .	1,2	3·7	·1
25 0 to 30 0 . .	·1	·8	0
Above 30 0 . .	0	·3	0

Pottery Trades.

The pottery trades are a group of trades producing pottery, closely allied by reason of locality, process, and conditions, and include the making of general earthenware, china, sanitary tiles, and Rockingham and jet and brown ware. Women are employed direct or as attendants on others.

The numbers employed in 1901 and 1911 were :

—	Census 1901			Census 1911			% Increase or Decrease		
	Females	Males	Total	Females	Males	Total	Females	Males	Total
Earthenware, China, Porcelain, &c.	24,477	37,998	62,475	29,439	40,424	69,863	+20·3	+6·4	+11·8

During the last ten years great changes in methods of production, mechanical and otherwise, have been introduced, and women have been in consequence drawn into the trade in increasing numbers. A notable example is the development of casting. The caster, who is generally a woman, has almost entirely displaced the hollow-ware presser, who was generally a man. In the words of a working potter : ' Before the War it was pitiable to see the number of hollow-ware pressers, skilled handicraftsmen, begging for labourers' jobs ' Men casters receive piece-rates about one-third higher than the women. In casting, as in pressing, the process is complicated by the introduction of the team system, by which a skilled man or woman presses or casts the article, while an unskilled woman, who is paid 12*s.* per week, finishes it.

Since the War the pottery trade has been among the depressed ones, but its workers have transferred to other industries, *e.g.*, silk, and many of the men have enlisted, which has resulted in certain cases in a shortage of male labour, and especially of youths, who have been attracted by the good money to be earned in the coal pits. The skilled males employed in the trade are mainly elderly men.

Before the War women were employed as :

Decorators and Transferers.—Average wages 11*s.* to 12*s.*, save in the case of ground-layers, who receive about 20*s.* on piece-work rates.

Clay-workers—' pressers ' or ' jolliers '—women receive about 20*s.* per week on piece-work rates.

Pressers' Attendants—' finishers,' ' spongers,' ' towers,' and ' mould-runners ' (in which boys are sometimes employed). The wages earned by women on these

processes are from 10*s*. to 14*s*. per week, and the rates are piece-work rates if paid direct by the employer, and time-work rates if paid by the presser.

Warehouse Women—'sorters' are paid a time-rate of about 9*s*. per week.

Of recent years women have been introduced on the following work:

Decorating.

(*a*) '*Ground-laying.*' This process is held by the trade union to be a man's process, although women have come in at lower rates of pay during recent years. The process itself is, however, being displaced by 'aero-graphing,' which is a woman's process.

(*b*) '*Painting,*' where men have been almost entirely displaced by lithography, which has been done by women since 1900.

Flat-ware Pressing.

Women entered the trade 30-35 years ago on the smaller articles, *e.g.*, cups and saucers, and 4-inch and 6-inch plates. They were, however, refused admission to the union or recognition of any kind until about 1903. The first women were admitted at the time of the amalgamation of the union in 1906.

The women are paid at piece-work rates about one-third less than the rates of the men. Men earn 30*s*. to 32*s*. and women 20*s*. per week.

Since the War women have been employed on the pressing of 10-inch and 12-inch plates, and they are paid piece-work rates one-third lower than the men. The men claim that the women should be paid at the same piece-work rates as the men. To this the women appear to object, urging that the effect of the men's wage-rate policy will be to exclude women from the process since:

(*a*) Women require more supervision than men.

(*b*) Women cannot set their own machines, and require the assistance of a mechanic.

By an agreement between the unions and the employers the men who have enlisted are to be reinstated at the end of the War; women who have taken their places are to receive the same wage-rate as the men displaced, and a number of women are now receiving men's rate of pay in consequence, but it is stated that in some cases this condition is infringed. It is also stated that children above the school-leaving age, especially girls, are being employed in considerable numbers as apprentices on time-rates—girls at 2*s*., boys at 5*s*. per week. It is feared by the union that the abnormal number of apprentices thus introduced into the trade will undercut other classes of labour, especially women's labour, and consequently the labour of men.

A War bonus of 7½ per cent. is being paid to all workers who are employed direct, and the trade union expects its members who employ 'finishers' or others, on the 'tally' system, to pass on the bonus.

In the early part of the War the pottery trade was very depressed and the majority of its workpeople left for more remunerative employment, the men going largely to the collieries and to armament factories, and a few of the women to artificial silk-weaving in Leek. Since December the trade has shown greater activity and there has been a shortage of labour, not among the more skilled workers but among those less skilled. This is a notable exception to the general experience, and the reason appears to be that unskilled labour has found at the moment more remunerative employment elsewhere. The shortage of unskilled labour rather than a lack of orders is the cause of some of the short time in the trade. Generally, owing to the stoppage of German and Austrian, and to some extent French, pottery exports to the Colonies, U.S.A., and the United Kingdom, there is a big demand at the present time for all the cheaper grades of English pottery, whilst there is a slump in the richly decorated and high price goods. Probably owing to financial and shipping difficulties the bulk trade to U.S.A. and to South America is very quiet, so that many of the workers must be gradually diverted from the two classes of manufacturers of expensive pottery, and of bulk pottery for U.S.A. and South America, to the cheaper houses who are very busy.

Furniture.

Furniture being largely a luxury trade has been considerably depressed since the outbreak of war and is likely to remain so. The cheaper branches of the trade have been less slack than the other part, and certain firms have replaced men *polishers* by women, but as this is a woman's trade as much as a man's, especially since the last strike, the replacement is no new feature due to the War. In some cases, on the other hand, women French polishers have been unemployed owing to the shortage of skilled bench men.

Large furniture firms have taken contracts for tents, kit-bags, mosquito-nets, &c., and have taken on extra women to cope with the work, in some cases opening new factories for the purpose. Women upholsterers and women drawn from the lower branches of the tailoring trade have mainly come in to do this work.

Aeroplane contracts have also been placed with furniture firms, but up to the present women have only made covers for the wings and 'doped' them, *i.e.*, varnished, which again is normally women's work.

In some factories and workshops women are glueing ammunition boxes, but here the line of demarcation between furniture and packing-case making is an elusive one; it is not possible to state whether they are displacing men or not.

There appears to be no feeling among the furniture trade unions against the further employment of women so long as they are paid the same piece-work rates as the men. The view, however, taken by most trade unions and employers is:

(*a*) Much of the work is impossible without long training, which the women are rarely prepared to give.

(*b*) Much of it is too heavy for women.

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2. *Land Settlement for Ex-Service Men.*

By Christopher Turnor.

1. *The Importance of the Problem.*—From such evidence as is at present forthcoming, and arguing from what took place after the Boer War, there seems little doubt that a large number of men now serving in the Forces will elect a career on the land at the close of the War. If this is so, it is clear that the machinery for providing them with land should be created without delay, and be ready before we have the ex-Service men upon our hands, probably in their thousands. Nationally and imperially it is a question of great importance. Cultivators of the soil are more needed than any other type of citizen, both at home and overseas.

It is probable that when the War is over a time of slackness will come in urban industry, which will make it all the more important that the land should employ as many men as possible. The men settled upon the land must be settled effectively and under conditions which will as far as possible guarantee success. They must not merely be provided with land and then left to shift for themselves. Our Dominions are paying more and more attention to land settlement. Sound and attractive conditions have been created. If we are to retain our fair and necessary share of ex-Service men within the United Kingdom, we must create conditions of settlement at least as sound and as attractive.

While not grudging to our Dominions a share in the number of settlers, we must ever keep in mind that the first essential is to build up the agricultural population in the Mother Country, and from the overflow of that population to send out to our Dominions the type of population which they stand most in need of.

2. *The Sufficiency of Land in the United Kingdom.*—There is sufficient land available for a very large scheme of settlement at home. No attempt should be made to create settlements in every county. They should be created where the land and conditions are most favourable. Large areas of land change hands every year, and land for the ex-Service men could as a rule be obtained in the open market. Several hundred thousand acres of agricultural land change hands

every year. With the exception of heavy clay, nearly any type of soil is suitable for small farming.

If areas of not less than 1,000 acres are bought nearness to a station is not essential as the colony would be large enough to afford social amenities of its own and to organise a system of motor transport. The settler under proper guidance should make a good living off twenty-five to thirty acres in the case of a small farm and off five to ten acres in a fruit-growing and market-gardening district. As in the case of the Small-holdings Act, compulsory clauses will be necessary but probably would rarely be resorted to.

A certain amount of land would have to be taken from sitting tenants. There are many men holding two or three separate farms with aggregate area of from 2,000 to 5,000 acres, in districts well suited to small farming; for the general good it would be quite legitimate to reduce the area held by these large farmers.

3. *Suitability of ex-Service Men as Cultivators of the Soil.*—It is the opinion of many in this country that to be a successful small-holder, a man must have been brought up on the land; but that this conclusion is altogether unsound has been proved by the settlements in the United States and in our Colonies of urban artisans, which have succeeded admirably. But the conditions of settlement for men without previous agricultural training must be entirely different from the conditions under which trained agriculturists can fairly succeed.

There is no example up to the present time in the United Kingdom of a carefully thought-out land settlement scheme where the fundamental principles necessary to success have been observed. Settlements of ex-Service men can be successful only where the right conditions have been created.

4. *Conditions of Settlement.*—Certain guiding principles must be observed which have met with unvarying success wherever scientific land settlement has been undertaken. They are:

1. Ownership rather than tenancy.
2. Easy access to capital.
3. Settlement in colonies rather than in isolated units.
4. Effective expert guidance.
5. Co-operation, or at all events organised buying and selling.
6. The initial years must be made as easy as possible financially.

5. *Machinery.*—If ex-Service men are to be settled satisfactorily it is quite clear that they will have to be treated differently from the ordinary applicants for small-holdings.

As has been pointed out, in most cases they will be without agricultural knowledge, and therefore will require special conditions. The conditions advocated should from the point of view of securing efficiency be created for all settlers, but in the case of the ex-Service men they must be created or the movement will end in failure.

The County Councils, in settling small-holders, have paid little or no attention to the principles enumerated above, and which should be observed in all land settlement. The Small-holdings Act has not proved itself to be a Land Settlement Act.

Under it many tradesmen have been given a bit of accommodation land, or men already holding some land have obtained additional land, but the number of new cultivators placed on newly-equipped holdings is very small—only 754 up to the end of January 1914.

County Councils ought not to be asked to undertake this work. Few members of their Small-holdings Committees have in any way studied or understood the problem of land settlement. This work of settlement should be carried out by a Land Settlement Commission composed of highly qualified men and in many ways analogous to the existing Development Commission.

This Commission would naturally concern itself with settlement in the United Kingdom, possibly only England and Wales. But the question of settlement in the United Kingdom should not be kept in a watertight compartment. There should be another Commission or Committee possessing advisory and consultative powers only, which would review the question of land settlement throughout the Empire and endeavour to bring about an understanding between

the Home Government and the Dominion Governments and the Dominions *inter se* to co-relate the work of the different emigration agencies and to endeavour to check the loss to the Empire of men settling in foreign countries.

The time has come when the whole problem of emigration and settlement should be approached scientifically and an attempt be made to bring order out of the present chaos.

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3. *Employment of Disbanded Members of H.M. Forces.* *By* Captain R. WALKER.

FRIDAY, SEPTEMBER 10.

The following Report was discussed :—

On the Effects of the War on Credit, Currency, and Finance.—Report of a Conference called by the Organising Committee of Section F, consisting of Professor W. R. SCOTT (*Chairman*), Mr. J. E. ALLEN (*Secretary*), Sir EDWARD BRABROOK, *C.B.*, Professor C. F. BASTABLE, Dr. A. L. BOWLEY, Mr. AUSTEN CHAMBERLAIN, *M.P.*, Archdeacon CUNNINGHAM, Professor L. R. DICKSEE, Professor E. C. K. GONNER, Mr. FRANCIS W. HIRST, Professor A. W. KIRKALDY, Mr. D. M. MASON, *M.P.*, Professor J. SHIELD NICHOLSON, and M. E. SYKES.

The Organising Committee of Section F decided that a Report on the Effects of the War on Credit, Currency, and Finance should be submitted at the Annual Meeting. In order that this Report should be as full as possible it was considered essential to invite the co-operation of a number of experts from the City, and accordingly it was decided to proceed by means of a Conference rather than by the usual Research Committee. Of the original members Mr. Austen Chamberlain took part in the early deliberations and gave most valuable help. He retired on his appointment as Secretary of State for India. Professor Bowley resigned on undertaking work for the Ministry of Munitions.[18] The Organising Committee desires to thank those who devoted themselves to the making of the specialised investigations which were required, many of which involved great labour and the placing of valuable personal and business experience at the disposal of the Conference.

The method of investigation adopted was to divide the whole inquiry into four heads, namely : (1) The Direct Effect of the War on Credit. (2) Public Borrowing as Affecting Credit. (3) War Measures and Currency. (4) War and the Mechanism of Foreign Exchanges. Memoranda on these and related subjects were invited from the members of the Conference and from others. These Memoranda were circulated amongst the members with the request that they would return them, with comments, to the Secretary.

Memoranda were contributed by the following :—

Professor BASTABLE,	Mr. JOSEPH KITCHIN,
Sir EDWARD BRABROOK, *C.B.*,	Mr. ROBERT LUMSDEN,
Mr. E. J. DAVIES,	Mr. D. M. MASON, *M.P.*,
Professor DICKSEE,	Mr. S. METZ,
Mr. E. L. FRANKLIN,	Professor J. S. NICHOLSON,
Mr. DRUMMOND FRASER,	Sir R. H. INGLIS PALGRAVE, *F.R.S.*,
Mr. A. H. GIBSON,	Professor SCOTT,
Dr. C. K. HOBSON,	Mr. W. F. SPALDING.

Further, the main headings were divided into nineteen sub-heads.

[18] Mr. Chamberlain and Dr. Bowley resigned before the Report was drafted, and therefore have no responsibility for it.

I. *Direct Effect of the War on Credit in Great Britain.*

How has the money market been affected by: 1. Hoardings? 2. Changes in demand for commercial purposes? 3. Government demands? 4. Foreign demands? 5. Stock Exchange demands?

II. *Public Borrowing as Affecting Credit.*

(1) Effects of the regulations as to the issue of new Capital.
(2) Effects as judged by public and other deposits at the Bank of England and by the Bank Rate.
(3) Extent to which Capital is withdrawn from enterprise.
(4) Effect of borrowing in Great Britain by Allied Governments.
(5) What proportion should be maintained between the amount borrowed for the War and the amount raised by taxation?

III. *War Measures and Currency.*

(1) The Effect of Government Assistance to the Banks and Financial Houses in August 1914.
(2) Was there hoarding owing to the War by (*a*) Banks? (*b*) the public? What was the effect on the Stock of Gold?
(3) Emergency Measures :—
    (*a*) Treasury Notes.
    (*b*) Provision for the suspension of the Bank Act (4 and 5 Geo. 5, c. 14, § 3).
    (*c*) The Moratorium.
    (*d*) Postal Notes made legal tender.
(4) How far were these measures (*a*) Necessary? (*b*) Effective? (*c*) Desirable? What provision, if any, should be made for the withdrawal of Treasury Notes?
(5) What was the effect of the increased paper currency on prices?

IV. *War Taxation.*

V. *War and the Mechanism of the Foreign Exchanges.*

(1) What was the effect of the outbreak of War on the Rate of Exchange?
(2) What have been the principal fluctuations since and their causes?
(3) How far were these fluctuations due to causes inseparable from the War, and how far were they preventable?
(4) How far are the reasons generally assigned the true reasons?

These questions were circulated amongst those who were judged to be able to supply first-hand information upon special points, and replies have been received from the following :—

Professor W. Boyd Dawkins, *F.R.S.*,	Mr. A. W. Kiddy,
Mr. Barnard Ellinger,	Professor Oldham,
Lord Eversley,	Sir George Paish,
Mr. J. A. Hobson,	Mr. W. Favill Tuke,
	Mr. Sidney Webb.

Several meetings of the Conference were held in order to define the scope and character of the inquiry and to determine the best methods of procedure; also to discuss the Memoranda, replies to questions, and the comments upon these. The members feel strongly that the time is not ripe for the presentation of a final Report, and that which follows is to be regarded as an interim one. Though necessarily incomplete, it has the advantage of attempting to present a picture of momentous events while most of them were fresh in the minds of those who had special opportunities for observation. Thus while the present Report is wanting in finality, it will aim at focussing a body of reasoned opinion upon the causes and proximate effects of credit movements during the first year of the War. However much present judgments may be shown by subsequent events to have been in error, in the opinion of the Conference it was essential that they should be recorded.

I. *Summary of the more important Emergency Measures during the year 1914.*[19]

Events have moved so rapidly within the last twelve months that even comparatively recent occurrences seem to have become remote. The rush and pressure of the times have been such that one is liable to forget matters which happened only a few months ago and would in other circumstances have been regarded as of the highest importance. Accordingly, for the sake of what follows, the following brief record of dates and facts may be pardoned in order to prevent digression in the later parts of the Report.

In the early summer of 1914 credit in Great Britain and on the Continent was normal, with perhaps a tendency towards uneasiness. There is an almost inevitable disposition for people to claim wisdom and foresight after the event, but, judging from the quotation of Consols, there was small anxiety. The fluctuations in 1913 had been 75¾-71 and the closing price on June 25, 1914, was 74¾-75, a price well over the average of the previous year. Early in July there were signs of caution in the chief Money Markets, following the assassination of the Archduke Francis Ferdinand at Sarajevo on June 28 The progress of negotiations between Austria and Serbia seems to have produced little effect, and even the presentation of Austria's ultimatum to Serbia on July 24 did not cause any marked uneasiness in London, as it was the general impression that the War would be localised. On the 25th there was a panic on the Vienna Bourse, while in London Consols fell to 72¼. Between that day and the following Tuesday (28th), when Austria declared war against Serbia, was a time of growing anxiety. In the week ending on Wednesday, 29th, Consols had fallen 4½, Belgian 3 per Cents 4¾, French 3 per Cents 6, Russian 3½ per cent. Bonds 5, Russian 5 per Cents (1908) 8½, Austrian 4 per Cents 8. By this time all the Stock Exchanges had closed except London and the provincial Exchanges, New York and the official (parquet) Paris Exchange. The Bank Rate was raised from 3 per cent. to 4 per cent. on Thursday the 30th. Remittances, both in payment of Stock Exchange accounts due by foreigners as well as the calling in of credits due from abroad, ceased except from America, while the closing of all the Continental Stock Exchanges except the official Paris market caused large quantities of International stocks to be offered for sale in London. It so happened that this period of extreme tension coincided with the date fixed for the settlement, which had been arranged for July 27-July 29. The failure of foreign clients of brokers to remit the sums due in London for the settlement made the position of these brokers precarious, and one important firm with foreign connections failed, while it was currently reported that many firms were prepared to hammer themselves. The failure of foreign remittances to the Stock Exchange affected transactions made before the crisis; but, after the outbreak of hostilities with Serbia, there was a steady pressure of sales from the Continent. The effect of these was a reduction in the price of securities, and this at once re-acted on those stocks held on margin. Loans on Stock Exchange securities at this period amounted to about 80,000,000*l*, of which 60,000,000*l*. was lent by the Joint Stock Banks and the remainder by other bodies. A continued fall in quotations would cause the margin to disappear, and therefore the lenders would call for additional security or they might call for repayment of the loan when due through anticipation of having to meet pressing demands themselves. The latter course was adopted by some, which threatened a further fall in the prices of stocks, and this again, if allowed to continue, would have depreciated the stocks held by banks, which would again have been serious if necessity arose for the liquidation of a part of these holdings. If demoralisation in the Stock Exchange was to be avoided, some action had to be taken upon Thursday, the 30th, and it was decided to close the Exchange.

The closing of the London Stock Exchange was the first of the series of Emergency Measures; and, to some extent, it influenced those that followed.

[19] The inclusion of this Summary involves a change in the numbering of the succeeding sections.

Prompt and decisive action was absolutely necessary; but, had time for reflection been available, it is possible that less drastic measures would have sufficed. The closing of the Exchange was not the only event of first-class importance on that memorable Friday. Bill-brokers were in the habit of borrowing largely from the Joint Stock Banks upon the security of the foreign bills they hold. During this week some of the banks called in their loans from the bill-brokers, who were forced to have recourse to the Bank of England either to borrow there or to discount their bills. The sums involved were large. In normal times it is supposed that the Joint Stock Banks lend about 100,000,000*l.* to bill-brokers in the form of credit at call or short notice. In the ten days ending August 1, the Bank of England's holding of 'other securities' increased by 31,700,000*l.*, the greater part of which is understood to have represented loans to the bill-brokers to meet the calls on them by the Joint Stock Banks. These large demands on the Bank of England were one cause of the rapid rise in the Bank Rate, which after being 4 per cent. for one day (Thursday, July 30) was doubled on Friday and was increased to 10 per cent. on Saturday, August 1. Concurrently with the difficulties of the bill-brokers there were the even greater ones of the accepting houses. These institutions in effect guarantee that a foreign bill (arising out of a trade transaction either between this country and a foreign country or between two foreign countries) will be met at maturity. It is largely by this device that London is the financial centre of the world, and it is estimated that one half of the world's foreign trade is financed by British credit. The acceptances current at this time of the accepting houses and foreign banks in London amounted to between 300,000,000*l.* and 350,000,000*l.*, while those of the Joint Stock Banks are known to have been about 70,000,000*l.* But, just as in the case of the stock-brokers, remittances were not forthcoming or were delayed or could only be made with great difficulty. London early in the crisis began to call in credit. All the available bills on London were quickly purchased by foreign debtors for transmission to London. New bills were not forthcoming, and there were great difficulties in procuring gold for shipment, in some cases it was impossible. In these circumstances the position of the accepting houses was one of extreme hazard, and, as Mr. Franklin says, 'the immediate effect of the outbreak of hostilities was to break down the whole fabric of foreign exchange throughout the world.' On Sunday, August 2, a proclamation was issued which postponed payment of bills of exchange (other than a cheque or bill on demand) if accepted before the beginning of August 4 for a period of one calendar month from the date of its original maturity. On Monday, August 3, an Act, known as the Postponement of Payments Act (4 & 5 Geo. 5, c. 11) was passed which authorised the King to suspend temporarily by proclamation other payments besides bills of exchange.

So far the dramatic events of Friday, July 31, and Saturday, August 1, have been considered from the point of view of the reaction of the crisis on credit as regards foreign remittances. There remains the position in relation to internal credit. It appears that the Joint Stock Banks, or some of them, expected and prepared for considerable internal demands from their depositors. Mr. A. H. Gibson says that 'the direct effects of the War on credit, as measured by the attitude of the British public during the early stages of the crisis, show that the loss of confidence was extremely slight. There was no run on the Joint Stock Banks or on the Savings Banks, and what degree of hoarding of gold took place at the commencement of the crisis was probably due to the lead given by some of the Joint Stock Banks paying out Bank of England notes instead of gold. This action caused a large number of people to whom notes had been paid to take them to the Bank of England to change them into gold which was required for holiday purposes. Almost without exception the reports of the Savings Banks for the year 1914 prove how trivial had been the influence of the crisis on their accumulated funds, the main influence having been a slight check to new business.' There was a somewhat general apprehension prior to the issue of new Treasury Notes that, where a creditor insisted on payment in the form of legal tender, there might not be sufficient legal tender to meet all demands. The figures showing the loss of gold from London to the provinces show that there were considerable internal demands for gold, the gold lost by the Bank of England from this cause having been 1,213,000*l.* during the week

ending July 29, and as much as 8,211,000*l.*[20] in the next week, which included the days during which mobilisation took place. When it is remembered that Great Britain was not as yet at war, the financial situation was evidently serious. On August 1, Germany declared war upon Russia, and the next day a state of war existed between Germany and France. War between Great Britain and Germany was declared on Tuesday, August 4. Prior to the latter declaration, which might be expected to have affected our Money Market most, there had been the breakdown of the foreign exchanges and the closing of the Stock Exchange. It had been necessary to support the accepting houses by the Moratorium in their favour of August 2. Scarcity of legal tender was felt, and there was an apprehension in many quarters that war between this country and Germany would result in further grave disorders of credit. This was the situation which had to be faced on Sunday, August 2, and Monday, August 3. Fortunately the Monday was a Bank Holiday, and by proclamation the Tuesday, Wednesday, and Thursday were appointed as special Bank Holidays, thus providing five days (if the Sunday be included) for the preparation of further Emergency Measures. An Act, known as the Currency and Bank Notes Act (4 & 5 Geo. 5, c. 14), was passed on August 6, authorising the Treasury to issue Currency Notes for 1*l.* and 10*s.* as legal tender for any amount. The holder of a Currency Note is entitled to obtain on demand during office hours at the Bank of England payment for the note at its face value in legal tender gold coin. Postal Orders were to be temporarily legal tender for the payment of any amount. This provision was revoked as from February 3, 1915, by proclamation. Under Clause 3 of this Act the Bank of England and any Scottish or Irish Banks of Issue may issue notes in excess of the limit fixed by law so far as temporarily authorised by the Treasury and subject to any conditions attached to that authority. Banks of Issue were indemnified against any liability on the ground of excess of issue after August 1 in pursuance of any authority from the Treasury. The former provision may perhaps be termed a suspension of the Bank Act; but, unless the legal limit has been exceeded, no formal suspension has actually taken place. Under these circumstances it is more correct to describe the arrangement as providing the machinery by which the Act may be suspended had the need arisen. Further Treasury Notes were issuable to bankers through the Bank of England up to 20 per cent. of their liabilities on deposit and current accounts.

Closely connected with these measures was the proclamation of August 6 under the Act 4 & 5 Geo. 5, c. 11, postponing other payments besides bills of exchange till September 3 (subsequently extended till November 3), with certain exceptions, the chief of which were payments of wages or salary, sums not exceeding 5*l.* dividends on trustee stocks, cashing of bank notes by the issuing banks, payments by Government Departments (including Old Age Pensions and liabilities under the National Insurance Act). These measures provided for the re-opening of the banks on Friday, August 7, upon a basis which, if artificial, was believed to have protected the banks. But that protection was founded on the Moratorium, which was so strange to English practice that a few years ago it was described as 'a strange beast inhabiting the Balkans.' It was necessary in making the first steps towards more normal conditions that foreign exchange should be restored and the Stock Exchange re-opened. As regards the former, exchange transactions in the early days of August were remarkable. The value of the sovereign rose as much as 30 per cent. in a single day in New York. On the other hand, owing to a temporary adverse balance due to France, the sovereign depreciated in Paris by 4 per cent. Between August 12 and September 5 a scheme had been formulated which provided that the Bank of England would provide acceptors with funds to pay all approved pre-Moratorium bills at maturity. The Bank was entitled to interest on these advances at 2 per cent above Bank Rate, and undertook not to claim repayment of any sums not recovered by acceptors from their clients till one year after the end of the War. The Joint Stock Banks undertook with the assistance of the Bank of England and the Government to finance new bills upon similar terms. The Government

[20] A large part of this sum would be held by banks in anticipation of heavy withdrawals by their depositors.

guaranteed the Bank of England against any loss which it might sustain in carrying out this scheme. This guarantee received statutory sanction by the Government War Obligations Act, 1914 (5 Geo. 5, c. 11). Loans to the Stock Exchange were next taken in hand. Under a scheme for Government assistance, dated October 31, as regards Account to Account Loans which had been made on the security of stocks by lenders other than banks 'to whom currency facilities were open,' or members of the Stock Exchange, the Government arranged with the Bank of England to advance 60 per cent. of the sums outstanding on July 29, securities being valued for purposes of such advance at the making-up prices of July 29. The Bank undertook not to press for repayment until twelve months after the conclusion of peace, the rate of interest being 1 per cent. above Bank Rate, with a minimum of 5 per cent. The banks to whom currency facilities are open undertook not to press for repayment of Account to Account Loans nor to require further margin until twelve months after the conclusion of peace. The total advances on foreign bills under the Government Guarantee were 120,000,000*l.* The sum advanced on pre-Moratorium bills to enable acceptors to meet their engagements at maturity was 60,386,000*l.*, and it was estimated that at the end of the War bills aggregating 50,000,000*l.* would remain in 'cold storage.'[21] The advances to the Stock Exchange by the Bank of England under the Treasury scheme of October 31 were returned at 520,059*l.*[22] The way was now prepared for completing the July settlement on the Stock Exchange, and a patched-up settlement was effected on November 18. Meanwhile, though the Exchange remained closed, dealings in stocks had been effected by negotiation and a scale of minimum prices had been drawn up by the Committee. The general Moratorium having come to an end on November 3, there was no reason to delay the opening of the Exchange, and this event took place on January 4, 1915, under somewhat drastic regulations imposed by the Treasury.

II. *The Direct Effects of the War upon Credit.*

Having traced, descriptively, the external results of the earlier months of the War on credit, we propose in the present section to inquire into some general questions relating to the effect of a state of war of the magnitude of the present struggle upon credit considered as far as possible in isolation from Emergency Measures. From the point of view both of practical finance and of economic theory, the consequences of a remarkable and sudden strain upon credit are of surpassing interest. While the outbreak of previous great wars has occasioned somewhat similar disturbances, the long period of cessation from contests between great Powers as well as the more highly developed organisation of modern credit render it advisable to consider the position at the present time *de novo*. From the standpoint of the economist it is unfortunate—while from that of the citizen it may have been fortunate—that complete materials for the observation of the unmitigated effects of the present War upon credit have been largely modified by counteracting influences, many of which were deliberately designed to counteract the direct consequences of hostilities as affecting the credit system in this country. In particular, as already shown (above, p. 587), the closing of the Stock Exchange took place before Great Britain was involved in war. Accordingly direct observation of the exact effects of war on credit cannot be made with completeness, though we consider it advisable to record such results as we have been able to obtain.

Credit is an organic growth. The normal condition assumes a certain degree of stability in the environment in which it works. In the usual credit cycle, though conditions vary as between the maximum and minimum points of expansion, in both a great number of the factors which affect the calculations of business men remain the same or are altered only to a very slight extent. War on a large scale either changes all conditions or (what is temporarily of equal importance concerning credit) it gives rise to the fear that all conditions may be altered. On the material side, war makes great inroads into the store of commodities and many calls on services while it deflects a large amount of

[21] *Hansard, Commons*, lxviii. p. 1545.
[22] *Ibid.* lxxi. p. 853.

labour from productive to destructive purposes. 'Credit,' as Mr. A. H Gibson puts it, 'assumes that goods will be brought to market, or be produced in due time, and sold, and that securities, which in reality have their capital value based on future productive power, will not materially fall in current market values through lack of confidence in future production. War materially weakens both these assumptions. When war shakes the foundations of confidence, it is obvious that it must immediately cause a serious restriction in the mobility or transfer of credit, and consequently reduce, for the time being, the rate of current and future production, for production cannot obviously be carried on without the transfer of credit; and the community suffers through the restriction of credit.'

Allusion has already been made to the difficulties of the accepting houses, the bill-brokers and the Stock Exchange. These reacted on the resources of the Joint Stock Banks, for the effect of the War had been to solidify assets hitherto regarded as liquid. The financial life of the City appeared in danger of being frozen at or near its source This was not so in reality, for the ultimate basis of credit is the future goods and services which can be relied upon to come to market later. Not only does war make it uncertain that some of the anticipated future production will reach the market; but also it makes a violent alteration in the relative values of capital goods and consumable goods. 'For the purposes of war only the right to goods, consumable now or soon, is useful.'[23] Thus there is inevitably a double revolution in credit occasioned by war, first in the widespread falsification of anticipations, and secondly in the valuation of immediate consumable commodities Both tendencies arrest the mobility of credit instruments and some of them become temporarily immobile; and, to the extent to which this phenomenon exists, credit temporarily ceases. It is estimated that the assets which the Joint Stock Banks had available in a comparatively mobile form—consisting of the gold and Bank of England notes which they held in their strong-rooms and tills and balances at the Bank of England—did not exceed 15 per cent. of the liabilities to depositors Loans at call or short notice were largely uncallable. Stock Exchange securities held either as investments or collateral security were to a considerable extent unsaleable; during the first week they were altogether unsaleable except at a dangerous sacrifice. Bills of exchange in the banks' own portfolios might or might not be met at maturity, and bills which the banks had accepted themselves might have to be met out of the banks' own resources. Thus a large part of bankers' resources were in danger of becoming immobile and solidified.

There were four main causes which combined to 'immobilise credit' at the outbreak of War:

(1) The fear by borrowers that they might have to repay immediately large amounts of credit which the lenders had transferred to them previously on condition that it was withdrawable on demand. A considerable part of this borrowed credit had been retransferred to others who desired to anticipate the proceeds of future sales or services and it was not callable immediately.

(2) The actual calling in, or attempt to call in, by certain banks, financial houses, and other institutions of large amounts of credit lent on demand.

(3) The general fear (until Treasury Notes were issued) that, if the lender insisted on the borrower repaying credit in the form of legal-tender currency, there might not be sufficient legal tender to meet all demands.

(4) The inability of foreign correspondents, owing to the collapse of the exchanges and other reasons, to remit credit to this country to meet maturing liabilities and other demand calls.

Elsewhere we discuss the effect of the Emergency Measures. These have aimed at re-establishing confidence, and they have succeeded in restoring the mobility of many forms of credit immobilised at the outbreak of war. But this is not a complete restoration of credit. As long as any Emergency Measures remain, to that extent there will be a failure to reach the standard of normal credit. Its main characteristic in this country was its spontaneous character, and necessarily as long as artificial and extraneous devices are required, the

[23] *Econ. Journal*, xxiv. p. 486.

position will be something intermediate between confidence and credit in the fullest sense of the word. In fact, the progress towards a normal return to credit will be marked by the gradual recall of successive Emergency Measures. When credit is sound, just as in the case of a healthy man, it does not need tonics, nor is it conscious of its own state. It works largely intuitively. All questioning, even a demonstration of 'its inherent soundness,' is an evidence that there is some danger of a failure of complete confidence at one or more points. The sound state of credit is that which needs no external help.

III. *Public Borrowing for the War as Affecting Credit.*

(i) *General Effects of Public Borrowing on Credit.*

Public borrowing may be regarded from two points of view. From the first or abstract point of view, Credit is based on claims to goods and services; from the second or concrete point of view, Credit is measured by prices on the Stock Exchange or by the rates of interest current in the Money Market.

Loans imply interest, and interest implies taxation in future years. The actual subscription of War Loans involves the handing over to the Government of claims to consumable goods and services for the destructive purposes of war, in return for which the Government gives the subscribers a transferable lien on future goods and services.

Extensive borrowing by Governments reduces the mobility of existing credit; because the payment of calls, as well as the expectation of further loans, reacts on the previous state of credit. As already shown, the outbreak of hostilities tends to contract credit not only within the area directly affected but in adjoining areas. In a great war the uncertainty extends to almost every market for capital. Thus war results in a general rise of interest. That rise is accentuated in a belligerent country both by the risks of war to it and by the contraction of its usual production through the calls on its productive power and also by the necessity for public borrowing. The State now exerts an urgent demand for capital in competition with, or even to the exclusion of, the remaining demands for industry. That demand is supplied from various sources. First, most of the floating supply of capital (namely, that capital which has not as yet been definitely committed to specific production) is subscribed, then circulating capital which has been diverted from its usual uses owing to the industries employing it having ceased or being contracted through the existence of hostilities. Further, sums are found by the postponement of repairs and renewals which were required to maintain the full efficiency of production. Foreign investments are sold to a greater or less extent. The latter source of supply can only be tapped by an increase in the rate of interest on Government loans lessening the disparity between the yields on home and foreign investment. The increase in the rate of interest offered by the Government has the further effect of being a direct incentive to new savings. It is to be remembered that the Government not only borrows but it also disburses the capital it raises. Many of these disbursements are made within the country, and a high rate of interest acts as a direct incentive to the saving of a considerable part of these as well as to increased economy amongst the remainder of the community. In the first War Loan of a series, the larger proportion of the subscriptions will be drawn from floating capital, but later issues depend for their success to an increased degree on new savings; and, in the present instance, these must be in excess of those made in time of peace. Hence the rate of interest offered in order to induce such additional savings will be high and will tend to increase. Thus the most evident effect of extensive Government borrowing, as has been shown by the two War Loans, is the tendency towards a rise in the price to be paid for each successive loan, *i.e.*, the rate of interest will rise, not only for Government loans, but for all borrowing. This is no new fact in English history, and this tendency may be illustrated by a table giving the average price of Government Stock before, during, and after the Napoleonic Wars.

Consolidated Three Per Cents.

Period	Average Price	Period	Average Price
1792	84⅜	1810–14	62½
1793	75⅝	1815–19	69⅞
1794	67½	1820–24	78⅛
1795–99	58⅝	1825–29	84 3/10
1800–04	63¼	1830–34	85½
1805–09	63	1835–44	92⅛

The quick rise in Government credit after Waterloo explains the success of the great conversion schemes of 1822, 1824, and 1830, all of which involved a material reduction in the rate of interest. One inference to be drawn from the above table is that all loans issued during the present War should bear early dates of redemption, so that the Government may convert them into loans bearing a lower rate of interest if the conditions of the Money Market ten or fifteen years hence permit such an operation. Pitt floated some of his War Loans at an enormous discount, yet they were being redeemed, before the Boer War sent down the price of Consols, at a considerable premium.

Let us see how the rise in the rate of interest is demonstrated by the terms on which the two War Loans have been issued. The first loan was 350,000,000*l.* of 3½ per cents. at 95*l.* : the loan being redeemable in thirteen years (or in ten years at the option of the Government). The yield was thus 3½ per cent. plus a bonus of 5*l.* per cent. on redemption at par in 1928, or three years earlier if the Government should so choose. At the time when this first loan appeared, therefore, the credit of the British Government stood at something between 3¾ and 4 per cent.

The second War Loan, which appeared at the end of June 1915, was made on a very different basis. This time it was a 4½ per cent. loan, at par, and redeemable in 1945, or at any date after December 1, 1925, at the option of the Government. The terms, moreover, were really more favourable to the investor than appears at first sight, for (1) a full half-year's interest is payable on December 1, although the instalments will not be completed until October 26, and (2) it is provided that for every 100*l.* held by a subscriber to the new War Loan he may obtain another 100*l.* in exchange for the same amount in the old War Loan on payment of the difference of 5*l.* in the respective prices of issue. For 100*l.* held in the new War Loan, the subscriber may obtain another 50*l.* in exchange for 75*l.* Consols which bear interest at 2½ per cent., or another 50*l.* in exchange for 67*l.* of 2*l.* 15*s.* per cent. annuities, or another 50*l.* in exchange for 78*l.* of 2*l.* 10*s.* per cent. annuities.

It is a condition of all these exchanges that new capital shall be raised to the extent of 105*l.* for every 100*l.* old War Loan, 100*l.* for every 75*l.* Consols, 67*l.* annuities at 2¾ per cent., or 78*l.* annuities at 2½. The market for these various securities has been affected by the regulation of the Stock Exchange approved by the Government fixing a minimum price for them, which has greatly restricted dealing in them. That minimum price is subject to variation, and has already been diminished in consequence of the issue of the prospectus of the new War Loan. The market price would probably be much lower if the market were free. As persons desirous of subscribing for the new War Loan either with or without the purpose of exercising the option of exchange will in many cases have to realise other investments, the Stock Markets generally might be expected to fall. Much will depend on the extent to which Consols and the annuities are offered for conversion. It is to be borne in mind that Consols are only an annuity, the capital value of which depends on the price current in the Stock Market. It has been necessary whenever the Government has desired to lower the rate of interest upon Consols to give the holders an option of being paid out at par, that is, at the nominal capital value corresponding to the annuity at the current rate of interest. Upon that, Consols now stand to produce interest at 2*l.* 10*s.* on a nominal 100*l.* By the proposals for conversion of 75*l.* Consols into 50*l.* War Loan that rate of interest is raised to 3*l.* per cent., but the nominal capital which the investment represents is reduced.

A further point has been well made by Mr. A. H. Gibson: 'When considering the matter of the effect on credit of great public borrowing for the purpose of war it has always to be borne in mind that the total amount expended is not altogether lost to the nation. Part of it is transferred in the form of profit to manufacturers and others engaged on war materials, and part of it is represented by ammunition and other Government stores, which the community has produced by working more strenuously, *e.g.*, by overtime and with more energy than it would have expended in peace times. But that part which is represented by ammunition and other Government stores, the energy to produce which has been diverted from productive industry, is, of course, irretrievably lost to the nation, as is likewise that part expended abroad on the purchase of ammunition and other stores required for the prosecution of war.'

(ii) *Effect of the Regulations as to the Issue of New Capital.*

In times of prosperity, applications for new capital are freely made and freely responded to, in general with the effect of somewhat depreciating the existing capital. Probably with a view to conserving the lending power of the country in the national interest, a temporary regulation has been made by which the Treasury is responsible for the sanctioning of any application for new capital before it can be made on the market. The grounds upon which the Treasury will base their action in this matter have not, so far as we know, been made public, but it is presumed that they imply some inquiry as to whether the public advantage would be served by the proposed issue. The Treasury may and do repudiate the idea that their allowance means approval, but the public will certainly infer that it does, and will give credit to the issue accordingly.

(iii) *Extent to which Capital is withdrawn from Enterprise.*

The free supply of capital towards industrial and other enterprises is interfered with by the condition of war and the public borrowing which is the necessary consequence in the following ways:

(1) The withdrawal from the resources of capitalists of the sums they subscribe to the public loans.
(2) In the depreciation of securities, which renders realisation difficult without loss.
(3) In the withdrawal from the labour market of workmen of the military age.
(4) In the contraction of the opportunities for investment with neutral countries.
(5) In the impossibility of investment with enemy countries.
(6) In the lack of enterprise and the feeling of uncertainty which prevail during warfare.
(7) In the anticipation of difficult times to come when the War is over.

Dr. C. K. Hobson has traced the effect of Government borrowing upon our investments in foreign countries. It is no longer possible, he says, to furnish the large streams of capital which normally flow into industries at home and abroad. It is more than doubtful whether Great Britain is maintaining its accumulated capital intact, and whether the wear and tear of plant, buildings, &c., in this country are being fully replaced. It is unfortunately clear that British holdings of foreign securities are being reduced. The appearance of the second War Loan was the signal for an outburst of selling, mainly of American securities. Hitherto the United States has owed us money. At the outbreak of war, according to the Secretary of the Treasury, American businessmen and bankers were indebted to London in the sum of approximately 90,000,000*l.* maturing by January 1, 1915. A large part of this amount was undoubtedly repaid, in the form of gold placed to the credit of the Bank of England in Ottawa, and in the form of food-stuffs, merchandise, and war equipment sent to Great Britain.

(iv) *Effect of Borrowing in Great Britain by Allied Governments.*

This takes two forms, (1) a direct subsidy by the British Government to its Allies, (2) the subscription in London of a loan to an Ally. We do not know to what extent assistance of the first class has been rendered, or whether it has been mainly in money or in kind; but it is obvious that our Allies have had to

depend largely upon the aid of our Government in providing material aid for carrying on the war in various ways. Two illustrations, however, may be given from official sources of our financial arrangement with France and Russia.

On February 15, 1915, Mr. Lloyd George, as Chancellor of the Exchequer, explained the arrangements made by him with the French and Russian Finance Ministers. The three Ministers decided that each country should raise money for its own needs within its own markets, except in the case of borrowing by the small States.

'We decided that each of the great allied countries should contribute a portion of every loan made to the small States who were either in with us now, or prepared to come in later on, that the responsibility should be divided between the three countries, and that at an opportune moment a joint loan should be floated to cover the advances either already made, or to be made, to these countries outside the three great allied countries.'

32,000,000*l.* had been advanced to Russia, and Russia had shipped eight millions in gold to England. In order to meet the difficulties of exchange which prevented Russian merchants discharging their liabilities in this country, Mr. Lloyd George had arranged to accept Russian Treasury bills against the bills due from Russian merchants, Russia collecting the debts in roubles in her own country.

The second illustration is taken from a speech made by the French Minister of Finance on June 3, describing the arrangement made by his Government with the British Government. M. Ribot reckoned that France would be spending almost 2½ millions sterling a day during the next three months, and he admitted candidly the great difficulty of finding that enormous sum, since both revenue and subscriptions to Treasury or National Defence bonds were coming in badly. M. Ribot estimated that the French Government would have to pay some sixty millions sterling to the United States, Canada, and England during the next six months. He proposes to pay this sum by a plan which the *Statist* considers excellent. The British Government has agreed to take 60,000,000*l.* of French Treasury bonds, repayable one year after peace, at a rate of discount equal to that which our own Government pays upon its own Treasury bonds, which is a very moderate one. In return the French Government agrees to advance to our Government twenty millions sterling in gold. By taking payment in this way the *Statist* says, somewhat optimistically, that our Government assures the exchange with the United States.

It is also to be noted that much money has been raised and expended for the benefit of refugees from the allied nations and in other ways for the relief of those affected by the War.

The actual closing of the Stock Exchange and the subsequent great restriction of its operations have prevented any direct subscriptions in the English market to loans to friendly foreign countries, and for some time to come such loans could only be floated successfully under exceptional conditions.

IV. *War Measures and Currency.*

(i) *Effect of Assistance by the Government to Banks and Financial Houses in August, 1914.*

With the effect of Government assistance to banks and financial houses we have already dealt in our 'Summary of Emergency Measures.' The main purpose of these measures was to prevent a serious derangement of credit and to impart a momentum to its machinery which would enable it to resume its operations. The banks were largely dependent on the accepting houses and the brokers, the bill-brokers were dependent on the accepting houses, and the ting houses were dependent on their foreign correspondents, who were, to the breakdown of the exchanges, unable to send the expected remit-

rst measure put into force was the Bill Moratorium proclaimed on ugust 2, and subsequently extended. The proclamation enabled postpone for a month payment of any bill accepted before August 4, ce for the amount plus interest to the new date of payment at the rent on the date of reacceptance. This proclamation gave breath-

ing time to acceptors who were unable, for various reasons, to take up their maturing acceptances, and consequently prevented a long chain of bankruptcies.

The next steps taken were designed to restore confidence among the banks, who have always on deposit with them large sums of credit withdrawable at call or short notice. The Government protected them by three important measures, which were very effectual in giving new confidence to the banks and the public :

(A) The General Moratorium proclaimed on August 6, and subsequently extended, gave the banks and other debtors (with certain exceptions) power to suspend payment for one month of debts payable before the date of the proclamation. But Bank Notes and Treasury Notes were convertible into gold during the Moratorium, being specially excluded.

(B) The Currency and Bank Notes Act of August 6, 1914, authorised the Treasury to suspend the Bank Act if necessary. An unlimited amount of Bank Notes would then have been available if required. The power to suspend the Bank Act was not used.

(C) The same Act also empowered the Treasury to issue one-pound and ten-shilling currency notes, which were to be legal tender in the United Kingdom. In a memorandum issued by the Treasury it was announced that currency notes would be issued through the Bank of England to bankers as and when required up to a maximum limit not exceeding, in the case of any bank, 20 per cent. of its liabilities on deposit and current accounts, in the form of an advance by the Treasury, the security being a floating charge on the bank's assets in priority to all other charges, bearing interest from day to day at the current Bank Rate. By this measure the banks were placed in the position of being able to obtain, if required, an advance of 225 millions of legal tender currency. In the initial stages of the crisis the banks took nearly 13 millions. The advances outstanding on June 9, 1915, only amounted to 139,000*l*. To give time for the Treasury Notes to be printed, August Bank Holiday was extended for the four days, Monday, August 3, to Thursday, August 6, inclusive.

With the object of placing the bill market again in a position to entertain new business, and thus provide international currency, the Government, on August 12, 1914, announced that the Bank of England, under Government guarantee against loss, would discount at Bank Rate, without recourse to the holders, all approved bills accepted before August 4. It was also announced that the acceptors of such bills discounted at the Bank of England might postpone payment at maturity by paying interest at 2 per cent. above Bank Rate varying. The effect of this measure did much to restore British credit abroad. The banks immediately sent large parcels of bills for discount to the Bank of England New bills accepted after the Moratorium, however, came forward slowly. Acceptors were not very willing to be drawn on except when the bills were drawn against goods consigned to England, because, so long as the exchanges were not working freely, there was still the danger of non-receipt of foreign remittance at date of maturity. The banks also showed disinclination to buy new bills from the brokers.

The Chancellor of the Exchequer, in his speech on November 27, stated that the total amount of bills discounted on the Government guarantee had been 120,000,000*l*. (This proved that of the 350,000,000*l*. to 500,000,000*l*. amount of bills which were outstanding at the outbreak of war most had been disposed of in the ordinary course.)

On September 5, 1914, the Government announced that the following important arrangements had been made with the Bank of England :

(A) The Bank of England will provide (where required) acceptors with the funds necessary to pay all approved pre-Moratorium bills at maturity. This course will release the drawers and endorsers of such bills from their liabilities as parties to these bills, but their liability under any agreement with the acceptors for payment or cover will be retained.

(B) The acceptors will be under obligation to collect from their clients all the funds due to them as soon as possible, and to apply those funds to repayment of the advances made by the Bank of England. Interest will be charged upon these advances at 2 per cent. above the ruling Bank Rate.

(C) The Bank of England undertakes not to claim repayment of any amounts not recovered by the acceptors from their clients for a period of one year after the close of the War. Until the end of this period the Bank of England's claim will rank after claims in respect of post-Moratorium transactions.

(D) In order to facilitate fresh business and the movement of produce and merchandise from and to all parts of the world, the Joint Stock Banks have arranged, with the co-operation, if necessary, of the Bank of England and the Government, to advance to clients the amounts necessary to pay their acceptances at maturity where the funds have not been provided in due time by the clients of the acceptors.

The arrangements announced on September 5, 1914, have since had a most important influence in rehabilitating the bill market and the exchanges.

(ii) *Was there Hoarding owing to War?*

(A) *By Banks.*—In the initial stages of the crisis some of the Joint Stock Banks unfortunately attempted to hoard their gold stocks at a time when the public wanted gold for holiday requirements. They paid out Bank of England notes instead of gold. This action caused a large number of people to whom notes had been paid to take them to the Bank of England to change them into gold which was required for holiday purposes. According to Sir R. H. Inglis Palgrave, this encashment of Bank Notes and so-called 'run on the Bank' would have passed unnoticed 'had not the access to the Bank been rendered difficult by the fact that since they were strengthening the ceiling of their vaults what would have been a throng was magnified into a crowd. Some people to enjoy the entertainment went to cash 5*l* notes.' Mr. Gibson observes that the other banks during the week ending August 5 withdrew large amounts of gold and notes from the Bank of England, where the Reserve fell during this week from 26,875,194*l*. to 9,966,649*l*.—a difference of nearly 17,000,000*l*.

(B) *By the Public*.—It is pleasing to record that with a few ignominious exceptions there was practically no hoarding of gold by the public. Since the outbreak of the War, however, there has been a gradual internal absorption of gold, the Bank of England having lost to provincial circulation the very large amount of 21,936,000*l*. in gold up to July 28, 1915, and from July 29, 1914. This absorption of gold must be considered as serious in view of the fact that the Treasury Notes outstanding on July 28 amounted to 45,387,000*l*. These notes have been absorbed by the home circulation since the outbreak of war, and should have displaced approximately their equivalent in gold. The Bank of England notes in circulation have also increased since July 29, 1914, by 3,825,000*l*. Therefore the total absorption of additional currency by the country since July 29, 1914, has been 71,148,000*l*. Doubtless, the holding of additional currency stores by the banks accounts for a large part of the absorption, but it is impossible to say how much, and some of the outflow is undoubtedly due to the increased currency requirements consequent on the extensive military mobilisation and the increased prices of commodities. Against the Treasury Notes outstanding on July 28, 1915, the Government held 28,500,000*l*. in gold coin and bullion, which amount, however, has been accumulated out of gold received from abroad since the commencement of the crisis, and has not been displaced from home circulation.

If the public were hoarding gold to anything like the extent of 50,000,000*l*. to 60,000,000*l*., one would naturally expect the Savings Banks to have experienced an abnormal amount of withdrawals since the commencement of the crisis. The reports, however, of the Savings Banks for the year 1914 proved, almost without exception, how trivial had been the influence of the crisis on their accumulated funds, the main influence exerted having been a slight check to new business.

There is evidence that the Joint Stock Banks have increased their reserves of currency since the commencement of the War, because their cash reserves have considerably increased. They have not necessarily done so, however, for the purposes of hoarding. They require additional currency to support their vastly increased deposit liabilities. By their subscriptions of 100,000,000*l*. to the first War Loan they indirectly created credits to a similar amount, and their subscriptions of about 200,000,000*l*. to the second Loan will also reflect itself in

a further addition of about 200,000,000*l.* to their credit balances by the end of the year, provided in the meantime they do not sell any of their investments to the public. Sir R. H. Inglis Palgrave writes: 'There has been, in fact, very little hoarding on the part of the public recently, far less than I remember took place during the panic of 1866. That some hoarding had taken place is clear from amounts in gold which have been produced in connection with payments for the new 4½% War Loan, but there is no evidence as to the date when these hoards were made. There are always people who will hoard.' Another correspondent suggests a reason for the absence of hoarding by the public—the 'war measures' were put into operation before the banks were reopened after *this* country entered the fray. He continues: 'Had not special measures been taken to prevent hoarding—such as the Moratorium and the special appeal to the patriotism of the public—I feel sure that hoarding would have taken place on a scale hitherto unknown. What produces hoarding is panic; and if the Government had not prolonged the August Bank Holiday as they did, the panic that set in on the outbreak of hostilities between Germany and France and Russia would have become so violent that the whole of commercial England would have become bankrupt. The fact is the Government did not give "hoarding" a real chance.'

(iii) *Emergency Measures to meet the Need for Currency.*

With regard to the Emergency Measures taken to meet the immediate need for currency, the most important step taken by the Government was the issue of Currency or Treasury Notes. The reason for this Note issue was that on the outbreak of war the banks feared a run on their deposits, and knew that they had not sufficient legal tender to meet possible demands. Their other resources were also solidified, and they felt that if they parted with considerable sums in gold the public might hoard it until after the War. There was also some apprehension that the supply of the circulating medium for ordinary business purposes might be insufficient It was therefore resolved that small notes of one pound and of ten shillings each should be issued by the Treasury. These notes were made legal tender—that is to say, they might be employed in paying a debt exactly in the same way as gold and silver coin or Bank of England notes can be used for that purpose. Arrangements were made for cashing the Treasury Notes in specie on demand at the Bank of England, and we learn from the Bank that the exchange of Currency Notes for gold is a matter of daily occurrence there, and, in fact, has been so since the notes were first issued. No mention, however, of the fact that Currency Notes are payable in gold at the Bank of England has appeared on any of the notes which have so far been issued.

The issue of these notes was a bold experiment; some difference of opinion prevails as to the wisdom of the step, and there is more doubt as to the advisability of continuing, and possibly of increasing, the amount of Government Notes in circulation. Some of the objections were referred to by Mr. Huth Jackson in his presidential address to the Institute of Bankers in November 1910, and are now endorsed by Sir Inglis Palgrave.[24] Mr. Huth Jackson quoted on this occasion from the works of Mr. Conant, who is a recognised authority on Banking and was the United States Delegate at the Hague Conference, and who wrote in his 'History of Modern Banks' as follows:

'A Government paper currency has rarely been issued to promote the convenience of commerce, and has seldom contributed to that end. Experience, as well as theory, has proved that Government paper money is essentially different in character from banking paper, and opens a Pandora's box of evil for every nation which uses it. The difference between a Government paper currency and bank notes is not one of experience or accident merely; it is a difference which is fundamental. Banking paper is based on business transactions, and is limited by their demands; Government paper is based upon the will of the State, and is limited only by its necessities. The almost

[24] Part of the statements made here were given by Sir Inglis Palgrave in an article on the 'Government Note Issue' in the *Bankers' Magazine* for April 1915, and are repeated with the permission of the Editor.

invariable rule of Government paper issues is that one begets another, until the entire volume exceeds the legitimate demands of business, upsets values, and goes beyond the reach of restriction of the metallic standard. . . . Even a limited issue of paper is maintained at par by a Government with much greater difficulty than by a well-regulated bank. The reason is fundamental. The Government has no quick assets. It is not wealth in the abstract that currency must represent, but quickly negotiable wealth. The Government has only two resources (beyond the cash in hand)—the pledge of public property and the power of taxation. The peculiar strength of a banking currency lies in the enormous mass of quick assets behind its demand liabilities.'

The objection made by Mr. Huth Jackson is so strong that it ought really to be decisive as to the continuance of the Currency Notes. Should there be any doubt on the subject there are several practical objections which ought to be remembered. One of these is the great risk of forgery. Another is the question whether they may not be a heavy expense to the State. A third objection is that a very large issue of them would have an effect upon prices. The amount of these notes issued is not, like the notes of a bank—payable in specie on demand, dependent upon the requirements of business, but it depends on the wants of the Government, which are completely different. The Currency Notes are made payable at the Bank, and, of course, they will be paid by the Government eventually—but, as mentioned before, the fact that they are payable at the Bank is not stated on them. There is hence—as the Currency Notes are not practically subject to the constant inspection at the issuing bank which ordinary notes payable in specie on demand are—a much greater risk of forgery. (We may add that a constant system of 'exchange' for the small notes of the issuing banks in Scotland and Ireland assists in obtaining the same results in their case.)

Again, small notes as those for 20*s*. and 10*s*. circulate among a much less educated class than the larger notes of the Bank of England do, and they thus rapidly become soiled, in which state it is almost impossible for any person to decide whether they are genuine or not. The first notes were very poorly executed. To render them safer from forgery a better design for the notes has since been employed, but the facilities for copying and reproducing any design by various processes are very considerable and no great dependence can be placed on the goodness of the design for preventing forgery Sir Inglis Palgrave says: 'Ready payment in coin on demand gives the best security against this. In the United Kingdom during the period of the suspension of specie payments at the beginning of the last century[25] the one-pound notes of the Bank of England were largely forged, while forgeries were far less frequent among the bank notes of the higher denominations.'

Sir Inglis here quotes a table showing the actual numbers of the forgeries in each denomination of notes over a series of years: 'After the war between France and Germany in 1870, notes as small as five francs were issued by the Bank of France. These were frequently forged. The Bank of France thought it desirable to pay all their notes, whether genuine or otherwise, in order to avoid the inconvenience which refusal to pay any of their notes might have produced. This I remembered hearing at the time. To be quite sure I inquired at the Bank of France last year, while the business of the bank was being carried on at Bordeaux, whether I was correct, and the Secretary of the bank assured me that the facts were as I have stated. He added that great precautions were taken and that the eventual loss was but small.'

There is hardly any need to enlarge on the great disadvantages which arise from forgery in the notes which form part of the general circulation of a country. Whether extensive forgeries of the notes are in fact taking place we do not know, and one of our correspondents says that 'all known coiners not in prison are now engaged in the manufacture of munitions.' Besides these difficulties which are inseparable from an issue of small notes, there is also the practical question whether there may not be an expense to the State from the issue of the Currency Notes. The figures on August 26, 1915, are as follows:

[25] The suspension of specie payments lasted from the year 1797 to 1821. See article on 'Suspension of Specie Payments,' Palgrave's *Dictionary of Political Economy*, vol. iii., p. 501.

Currency Note Issue.

Statement of August 26, 1915.

	£
Scottish and Irish Banks of Issue	—
Other Bankers	1,204,000
Trustee Savings Banks	469,000
Currency Note Redemption Account:	
Gold Coin and Bullion	28,500,000
Government Securities	9,586,000
Balance at the Bank of England	14,750,000
	£54,509,000

Proportion of gold to notes outstanding, 52·6 per cent.

This statement shows that at the end of August 1915 about 54,500,000*l.* of Currency Notes were in circulation, that there was held against them 28,500,000*l.* in gold with about 9,600,000*l.* Government securities, and that there was further a balance of 14,750,000*l* at the Bank of England.

The Currency Note issue is thus amply secured, but can any profit arise to the Treasury from the issue? We must first estimate the expenses. The best basis that we can find for estimating the cost at which the Treasury Note issue is being worked is found in the Report of the Postmaster-General. In his Report for 1903 the net expenditure of the Post Office Savings Bank Department is stated as 'representing an average cost per transaction of 5.93*d.*' Professor Dicksee maintains that there is nothing in common between transactions of this description and transactions in the Savings Bank Department. 'If there were,' he adds, 'it would be a simple matter for any competent person with up-to-date ideas to reduce the costs of the Post Office Savings Bank to a maximum of 2*d.* per transaction' At present there are no statistics available to show whether the cost of Treasury Notes equals or approaches the cost of transactions in the Post Office Savings Bank. But there is a statement in the evidence taken before the Select Committee of the House of Commons on Banks of Issue in 1875 which shows that the cost of a one-pound note circulation, kept in a reasonable condition, could not be much less than 1½*d.* per annum for every note issued. This would be a much smaller expense than that shown in the estimate based on the expenditure at the Post Office, but, as more than 93,000,000*l.* of Currency Notes had been cancelled up to August 1915, the expense of working the issue must be very large, and a profit can hardly be looked for. Nor is the amount of gold acquired for the Bank of England by the Currency Note issue really important considering the large reserves which must always be held against it.

On the other hand the experience of the Scottish and Irish banks of issue shows that an issue of one-pound notes can be maintained at comparatively small cost, and that in these countries notes of one pound circulate with great freedom, even in some cases being preferred to gold. In foreign countries, too, Governments have thought it worth while to issue notes of far lower value than ten shillings. For years Italy issued notes of one lira (9½*d.*), and France is now issuing one-franc notes, and even 50-centime notes are not unknown. Further, an allowance must be made for the fact that gold coin withdrawn from active circulation is, for the time being, protected from wear. Hitherto the Government has accepted responsibility for the loss in weight of gold coinage, and the stoppage of this loss should far outbalance the cost of printing notes.

(iv) *The Extent to which these Measures were Effective, Necessary, or Desirable.*

Our fourth question clearly invites a difference of opinion. We have already explained the various Emergency Measures, and in the process we have criticised them where criticism seemed to be required. Consequently we say nothing further about them here, but in order to place on record the objections which may possibly be urged against them we print here Mr. A. H. Gibson's summary.

The measures enumerated above restored confidence among the banks, who had standing over them the possibility of a general run from their depositors at a time when they were unable to convert any large part of their resources

into legal tender currency For the rapid restoration of confidence among the banks the Government measures must be considered as having been very effective.

In the absence of legislation providing that banking deposits over a certain amount should not be withdrawable without a certain notice first being given by the depositor, some measures of protection to banks were necessary in order to restore confidence among the banks. So far as the public were concerned, the experience of the banks has since shown that the protective measures enumerated were unnecessary. If there had been no extension of the Bank Holiday, and the banks had not refused to pay out gold to their depositors in the ordinary course of business, there is no reason to think that gold withdrawals from the banks would have been on a very abnormal scale. There would possibly have been a few extra millions paid out during August, but the drain could easily have been met without much effect on current stocks.

The measures enumerated were not desirable for many reasons :

(1) They tended to destroy confidence among the public, whilst admittedly creating confidence amongst the banks.

(2) The old proved banking maxims that 'the best way to restore confidence among depositors is to pay out smilingly in full the demands of any uneasy depositors,' and 'every restriction on gold going out acts as a restriction on it coming in,' were evidently early forgotten by the Government and the banks.

(3) The measures caused a loss in confidence in the banks by certain people who can never be expected to understand the machinery of finance. It will be many years before confidence in the banks is fully restored.

(4) There is reason to believe that the more or less forcible issue of Treasury Notes on the public by the banks is one cause of the continuous absorption of gold by the provinces; the public, on account of their preference for gold, showing a tendency to hoard what gold is paid out to them. The available evidence is that the issue of Treasury Notes has not conserved gold stocks, which was one of the objects of such issue, though in future there should be less public hoarding of gold if the Press make widespread appeals to patriotism.

(5) The Treasury Notes and Postal Orders have given considerable labour to the banks and the public, not being so easily handled and counted as gold.

(6) Obviously, if it were necessary to use Treasury Notes they should also have been issued in larger denominations than one pound and ten shillings, say, for 5*l*., 10*l*., 20*l*., 50*l*., 100*l*., 500*l*., and 1,000*l* In the event of a run on the banks it would have been easier for the cashiers to pay out the larger denominations than a greater number of the smaller denominations.

(7) The position of the banks and the fears it engendered during the early days of the crisis have proved that in future there must always be available large stocks of paper emergency currency for times of crisis, and the banks and other people must be in a position to obtain supplies on pledge of Government securities

Some criticism is directed against the closing of the Stock Exchange and the action of some of the Joint Stock Banks in the first days of the crisis. In two respects only had anticipation underestimated the magnitude of the effects of the War on the Money Market. 'The first was the scale on which foreign creditors became unable to meet their obligations to us and the strangling effect of this on our own Money Market; and the second was a lack of courage in the early days of the crisis on the part of our joint-stock bankers.'[26] The Stock Exchange was closed on and after Friday, July 31, and remained closed for the rest of the year. Was this drastic step necessary? Why was it taken? One authority believes it was not necessary, and he throws the blame for it on the banks. He reasons thus : 'Immense sums were lent by the banks on security of shares. The amount of the loan for which this security is good is ordinarily calculated by reference to the price at which the shares are quoted in the Official List If the quotation falls the bank may require their customer either to reduce the amount he is borrowing from them, or to put up additional security.' If he does not they may sell his stocks. If the Stock Exchange had remained open there would have been a great fall in prices and the banks would have seen their securities dwindling. 'There

[26] *Economic Journal*, September 1914.

was no guarantee that they would not have taken it into their heads to ruin a number of their customers. The ruin of these would have brought with it the ruin of brokers who had trusted them; and so the trouble would have spread from one class to another.'

On the question of Provision for the Suspension of the Bank Act we may again quote the opinion of Sir Inglis Palgrave: 'The experience of the only occasion on which the suspension of the Bank Act has occurred shows that it was fortunate for the trade and credit of the country that this suggestion was not carried out in 1915 During three crises which have occurred since the Bank Act was passed in 1847, 1857, and 1866, permission was given each time to suspend the Act. On one occasion only, in 1857, did the suspension actually take place. The strict limits of the Act of 1844 were only exceeded in the returns of November 18 and 25, 1857 [27] But the impression abroad was very injurious to this country It was considered that the United Kingdom had become bankrupt. It is quite true that internal anxiety was quieted, but the effect on our foreign trade was very different. As one of the few persons now living who can remember all the crises which have occurred in this country since 1845 I still bear in mind the distress which followed. The crisis of 1866 was indeed more terrible in England, but the effect on the Continent in 1857 was very serious. The crisis of 1847 was severe, but the resulting troubles were far less than those of the two later crises The main reason for this was that in 1847 the difficulties were caused by the too rapid extension of our Railway System, and through speculations that resulted. Great distress was caused at the moment, but the railways remained and were of such service to the trade, industry, and the economic conditions of the country that the troubles were soon overgot.'

The power of suspending the Bank Acts of 1844-1845 is given in Sections 3 and 4 of the Currency and Bank Notes Act, 1914. The terms are more sweeping than any alteration of the legislation established by Peel that has yet been suggested Section 3 enacts that not only the Bank of England, but any Scottish or Irish Bank of Issue 'may, so far as temporarily authorised by the Treasury, and subject to any conditions attached to that authority, issue notes in excess of any limit fixed by law.' Section 4 enacts that 'any bank notes issued by a bank of issue in Scotland or Ireland shall be legal tender for a payment of any amount in Scotland or Ireland respectively, and any such bank of issue shall not be under any obligation to pay its notes on demand except at the head office of the bank, and may pay its notes, if thought fit, in currency notes issued under this Act' The power thus given to suspend the Bank Act of 1844 and the Bank Acts of 1845 has not at present been exercised.

The use of postal orders as legal tender was very small. By most people it seems to have been welcomed as an opportunity of securing these convenient means of remittance for small amounts without paying the usual poundage. The facilities may have been useful, and no objection can be taken to the measure. After a time these facilities were withdrawn, and no one complained. The Moratorium, however, was a very serious innovation in British financial policy, and can only be justified by the great seriousness of the crisis which it was designed to meet. Undoubtedly it was useful in giving people time to think, and to gather together their resources. But as actually constructed by successive Proclamations under the Postponement of Payments Act it showed certain defects, which are well set out by Professor Dicksee. He admits that both the four days Bank Holiday and the Moratorium were probably necessary in order to give time for reflection and recovery. 'But,' he continues, 'while they may have served to allay panic, and perhaps even to restore confidence, in the nature of things they could not re-establish Credit, for Credit is a matter of trust, rather than of calculation.'

The Moratorium was somewhat unsatisfactory in several ways. It extended the time for the execution of contracts involving the payment of certain kinds of debts, but not the time for the execution of contracts involving the delivery of goods or the rendering of services. But many business houses that were under contract to deliver goods at stated intervals against payment on specified dates broke their contracts and refused to continue delivery, unless they could

[27] Palgrave's *Dictionary of Political Economy*, vol. i., p. 463, article on 'Crises.'

be assured that punctual payment would follow in due course. Thus a want of confidence, which in the first instance was confined to monetary transactions, was extended to dealing in goods. The same difficulty did not arise to any serious extent with regard to the rendering of services, because payments in the nature of wages or salaries were exempted from the provisions of the Moratorium; but those who were under liability to pay out large sums in wages were gravely inconvenienced, and sometimes obliged to suspend operations altogether.

(v) *Effect of Increased Paper Currency on Prices.*

We now come to what is perhaps the most controversial of all our questions, that of the effect of the issue of Treasury Notes upon prices.

Several distinguished correspondents send us memoranda which are very hostile to the continuance of these notes. Sir Inglis Palgrave expresses the view which is taken by most economists. He writes thus: 'The effect of an increase of the paper currency upon prices, if sufficiently large, is invariably to raise prices, in the same way as any other increase of the circulating medium, when this is not called for by an increase in the business done. The general increase in prices since the issue of the Treasury Notes may possibly be connected with that issue in some degree. Few things are more difficult to trace than the alteration in prices caused by the issue of a Government paper issue at its first inception. To employ a simile, if I may venture to do so, it is like watching the rise of the tide on a wide beach. Sometimes the waves appear to beat stronger, sometimes they retreat, and it is not till some considerable interval has occurred that the spectator can be certain that the water at his feet is really deeper. Those who will refer to what occurred when the payment of the notes of the Bank of France in specie was suspended after the year 1870 when a vast paper issue was made, and what is taking place now on the Continent from similar causes, will understand this. The effect on prices in this country during the suspension of specie payments early in the last century is another and a good example. The House of Commons even, by passing a Resolution moved by Mr. Vansittart, at that time Chancellor of the Exchequer, denied that the high price of bullion then existing was due to the over-issue of paper, but the effects which followed the resumption of specie payment showed conclusively that prices had been raised very considerably by the great increase of the currency.'

The most emphatic condemnation of Treasury Notes is that of Professor Shield Nicholson, who has denounced them in the columns of the *Scotsman* [28] and in the pages of the *Quarterly Review* [29] So far as gold is concerned, he argues, we might have expected to see a general fall in prices, since 'all the great foreign banks have taken to hoarding their gold, as if that were the height of financial wisdom.' Moreover, as the *Economist* index numbers show, the rise in prices since the War 'is the more remarkable as it set in in face of a continuous fall for the year preceding the outbreak.' The Money Market, he continues, has been 'in a state of otiose repletion, and the channels of circulation have been filled to the brim with emergency currency.' As a result the value of our imports has risen while that of our exports has fallen sharply. 'Inflated prices encourage imports and discourage exports.' Then there are difficulties at home, *e.g.*, the readjustment of wages to meet the general rise in prices. 'It cannot be denied that there has been a general rise in prices, which is exactly the same thing as a general depreciation of the currency, but many people object to the use of this latter phrase. They prefer to indicate their confusion of thought by saying that the rise in prices is the "natural" result of the War. On this view, prices in war-time simply rise because "it is their nature to," like the dogs that delight to bark and bite, and the opium that has the *virtus dormitiva*, whose nature it is to dull the senses.' One object of the note issue was the preservation of our stock of gold, and this policy is attacked by Professor Nicholson—'The maxim that a reserve of gold ought to be accumulated in ordinary times for use in an emergency has been strangely perverted into the maxim that in times of stress gold ought to be hoarded for liberation when the stress has passed.'

[28] February 17th and March 17th, 1915.

[29] 'The Abandonment of the Gold Standard,' April 1915.

As we have said, opinion on the merits of the Currency Note issue differs. Mr. Barnard Ellinger welcomes the issue. 'I think,' he writes, 'if the banks made a great effort to pay out Treasury Notes and the public were made to understand that it is desirable that they should use them instead of carrying about gold, not only would more gold flow into the Central Institution but an opportunity would not be lost of accustoming the public to the use of one-pound notes, should it be found desirable after the War to retain them as a permanent part of our currency, in order to strengthen our gold reserves. If the notes were withdrawn and instead of them one-pound Bank of England notes issued, so made as to be easier to count and handle than the present notes, I think the public would take them willingly and the tellers at the bank would be equally willing to pass them out, as they would not experience the present difficulty of counting them.'

Mr. Gibson denies flatly that Treasury Notes have had any measurable effect in raising prices. He argues that as the home circulation has absorbed over seventy millions of additional currency since the War began, the twenty-six millions of Notes not backed by gold have simply helped to fill up the additional requirements. He holds that in this country cheques are so much more used than coin or notes that we have practically lived on a paper currency for some time past. 'A far more interesting and important problem,' he adds, 'is the effect of the 400 millions or so of additional credit created by the banks themselves subscribing to the last two War Loans and Treasury Bills.' Mr. E. L. Franklin also believes that the issue of Treasury Notes, up to the present, has had no effect in raising prices. The total increase in the circulating currency is not, he thinks, greater than the amount of gold now hoarded by the public.

Mr. D. M. Mason, M.P., on the other hand, holds strongly that the notes ought to be withdrawn as soon as possible. He maintains that the effect of 'an abnormal issue of paper currency,' whether in bank notes or in Government notes, is to raise prices. With this view, if stress be laid on the word 'abnormal,' we are inclined to agree. An over-issue, he continues, is less probable in the case of bank notes, as they would be difficult to get into circulation. He sees no objection, however, 'to properly qualified banks having the right to issue notes, and provided the notes are made payable in gold on demand there need be no limit placed upon the issue, as the notes in the event of an excessive issue would probably be at once presented for payment.'

Each country is only capable of using a certain amount of currency for its daily and yearly requirements. This currency expands and contracts with the demands made upon it. If there is a surplus of currency and loanable credit in a country the rate for money falls and, like every other commodity, seeks a better market. The exchanges turn against the country in such a case and gold flows out until the value of money rises and checks the outflow and in turn tends to attract capital back to this country again. Mr. Mason quotes a letter from the *Economist* which compares the note circulation of the principal banks of Europe in March 1914 with the circulation a year later

	Note Circulation in March 1914	Note Circulation in March 1915	Increase in 1915
	£	£	£
Bank of England . . .	28,500,000	34,000,000	5,500,000
Treasury Notes	—	38,000,000	38,000,000
Total	28,500,000	72,000,000	43,500,000
Bank of France	232,000,000	444,000,000	212,000,000
Imperial Bank of Germany .	90,000,000	247,000,000	157,000,000
Bank of Russia	162,000,000	312,000,000 (estimated).	150,000,000
Austro-Hungarian Bank . .	89,000,000	178,000,000	89,000,000
Grand Total . .	601,500,000	1,253,000,000	651,500,000

This table, we may observe, makes no allowance for the large increase in the gold stocks of all the banks mentioned. So far as the Bank of England is concerned, Mr. Franklin, writing on August 13, says : 'Comparing the gold position to-day with that of August 13, 1914, I notice that the entire note circulation could be redeemed in gold, and the Bank would still have the same amount of gold in its vaults as this time last year, namely, 32 millions.'

Coming to the second part of the question as to 'what provision, if any, should be made for the withdrawal of Treasury Notes,' we find it more easy to agree upon a recommendation, and this is that the Treasury Notes should be gradually withdrawn. If paper money for sovereigns and half-sovereigns is still required, this should be provided by Bank of England notes of these denominations.[30] From this recommendation Mr. Franklin dissents, suggesting as an alternative that the issue should be adjusted until each note is balanced by its equivalent in 'ear-marked' gold. 'By this method the amount of circulating currency would not be increased, while the Government would have control of a large stock of gold.' We are by no means sure, however, that it is wise to leave a large stock of gold in the hands of a Government Department. A Chancellor of the Exchequer in difficulties might be tempted to raid it.

V. *War Taxation.*

What proportion should be maintained between the amount borrowed for the War and the amount raised by Taxation?

On this question it was not probable that the Conference would come to a unanimous conclusion. The general opinion is that no *fixed* proportion can be maintained in the case of a war which is not yet within sight of its end and has already cost a sum surpassing that spent in any previous war.[31] At the same time the Conference has no hesitation in agreeing with Professor Bastable's opinion that 'the need of immediate taxation is great.'

While it is difficult, and perhaps ultimately impossible, to discover any principle upon which the cost of a war should be divided between money raised by borrowing and money raised by taxation, nevertheless, since all loans, even when raised by national Governments, should be regarded as being repayable at some time in the future, the real choice is between paying by present taxation and paying by future taxation. By a curious irony the Imperial Government has found itself forced, by stress of circumstances, to adopt the rule, which it has imposed, amidst so many protests, on our local governing bodies—that loans shall be repaid at a fixed and early date. It is probable, no doubt, that the Government would have preferred the unilateral option of Consols, *i.e.*, of repayment at its option only. But the disastrous experience of Pitt, who issued his loans at a ruinous discount, and the risk of a refusal on the part of investors

[30] Sir Inglis Palgrave makes an interesting, if somewhat revolutionary, suggestion in this connection, namely, that the Bank should be allowed to issue its notes against suitable business securities. 'These might be first rate mercantile bills and floating securities of that class, the requirements of the Bank Act as to the holding of gold coin and bullion against the notes issued beyond the fixed limit of 18,450,000*l.* being suspended for the time while the Bank was directed to pay its notes in specie. If the Bank of England were left to its own judgment in the matter, as it was before the Act of 1844 was passed, there ought to be no anxiety that it would fail to provide for cashing its notes and meeting the demands on it in specie. The rate of discount might at times have to be raised to a high point if the foreign exchanges were much against this country, but this, as well as the arrangements needed for the maintenance ba[illegible]payments in specie, might safely be left to the management of the Bank of to d[illegible]nd.' As an alternative Sir Inglis suggests that the other banks in England stock [illegible]ales, whose rights of issuing notes have been gradually cut down since that a[illegible] r[illegible]uld be allowed, under proper safeguard, to make a new issue of small emergency
gold ought [illegible]ney Webb protests strongly against the attempt to assign any

[28] Fe[illegible]loans and taxes. 'No such *ratio*,' he writes, 'can have any
[29] 'Th[illegible]*amount* which it is economically desirable and practicable to

to subscribe to an irredeemable loan, have led to the adoption of a sounder policy. It is no doubt true, as Mr. Gibson suggests, that one reason for the early date of redemption, at the Government's option, is to secure the possibility of conversion to a lower rate of interest if the War Loan stands above par.

In the case of a local authority Parliament only permits borrowing for purposes which have a permanent value, such as the purchase of property or the building of a Town Hall, and it insists, in every instance, that a sinking fund shall wipe out the whole loan before, say, the Town Hall will need rebuilding. Thus at the end of the period the town possesses its Hall free of debt. Consequently the local sinking fund need only be fixed at the small percentage required to wipe out the debt within the forty or fifty years specified by Parliament. But in the case of money borrowed by a Government for a war the conditions are very different. The money has been spent, and there is no property or work of permanent value to show for it; it has gone like the money which a man borrows to keep his home going during an illness, not like the money which he sinks in building himself a house. Consequently a greater effort must be made to pay for it out of income rather than by borrowing. No doubt, when a successful belligerent gets an indemnity or an increase of territory, this is an asset to be reckoned against the new debt of the war; or, to continue our analogy, it is like a firm borrowing to buy the site for a new building. Clearly the smaller the war expenditure the larger the proportion which should be raised by immediate taxation Mr. Gladstone added very little to the National Debt as a result of the Crimean War, though he increased taxation immediately. During the Boer War laxer principles prevailed.

Now, however, with the rate of expenditure so enormously increased beyond anything known or thought of even fifteen years ago, precedents give little help, for the proportion raised under Mr. Gladstone is clearly out of the question. Nevertheless, some principle or proportion must be found. Interest on the War Loan must be met out of taxation: there can be no two opinions here. Two further annual charges must be faced, though both should gradually decrease, viz., Sinking Fund, and Pensions for the disabled and for widows and dependants of the slain. These charges, like that for the interest on the War Loans, naturally depend upon the length of the War itself, but all three charges will grow with each month that the War lasts. Another thing grows, and that is the rate of interest which has to be paid for each successive loan. The earliest batch of Treasury Bills was subscribed three times over at an average rate of discount of $3\frac{5}{8}$ per cent.; the first War Loan, issued on a basis of between $3\frac{3}{4}$ and 4 per cent., was subscribed with difficulty; and the second Loan required much advertising and appeals to patriotism before it could be floated at $4\frac{1}{2}$. And now, from Mr. McKenna's promise to accept $4\frac{1}{2}$ per cent. War Loan stock as payment for a third War Loan, if it should have to be issued, we must face the possibility of a debt at over $4\frac{1}{2}$ per cent. running far beyond a thousand millions.

Then it is a well-known fact that borrowed money is spent more extravagantly than income, whether by Governments or by individuals Finally, during a war, money is inevitably spent lavishly and everyone connected with war industries earns higher wages than in times of peace. Consequently the nation as a whole can bear more taxation now than it will be able to bear when peace comes and the war industries become slack again. Yet no fresh taxation was imposed by the 1915-16 Budget, and even the Interim Budget of November 1914 had only doubled the Income Tax and increased the Beer and Tea Duties, a rough-and-ready plan which was excusable at the moment but is indefensible as a permanent method of raising money for the War.

Detailed proposals for raising further revenue might lead the Conference into controversial topics, and have accordingly been excluded from its 'Reference.' Therefore we cannot endorse the fiscal proposals made by the Bankers' deputation to the Prime Minister and the Chancellor of the Exchequer, which are now supported by Mr. Barnard Ellinger. His argument runs thus:

'If the amount of indirect taxation raised through existing Customs duties were very considerably raised, so long as the Exchequer were receiving the same

total amount of revenue, any diminution of import due to the increased rate of taxation would, at the present time, be of great advantage to the nation, in so far as it would diminish the total sum of our imports. If the excessive taxation did not seriously diminish the imports, the Exchequer would of course gain in revenue. An increase of indirect taxation in the shape of Excise duties is also desirable, and no great harm could be done at the present time by driving this taxation up to or near a point at which it ceased to be productive. The Exchequer would get at least the same revenue as hitherto, and there would be a growth of saving available for loans, or alternatively the Government would get increased revenue.'

Direct taxation raises less controversy, and we think that the Income Tax might be raised beyond its nominal rate of 2*s*. 6*d*., especially if its graduation were improved and if it were extended, necessarily at a lower rate of charge, to a much greater number of taxpayers. Two considerations, however, must be borne in mind : a greatly increased tax (1) adds to the risk of false declarations or concealments of income, and (2) may deprive the Government of subscriptions to its loans. In order to obtain some definite estimate of the total cost of the War it is necessary to assume that it will end on a certain date. Mr. Joseph Kitchin, who has furnished the Conference with a very valuable and exhaustive memorandum, assumes merely for purposes of calculation that hostilities will continue until the end of November next, and that a further three or four months will be taken up by negotiations and the final ratification, during which expenditure will be on a heavy though on a reduced scale. On this assumption he works out the cost of the War as follows : 'Exclusive of (1) some 200,000,000*l* lent to the Dominions and our Allies, which will in due course be repayable ; (2) some 30,000,000*l*. spent in the purchase of wheat, meat, sugar, and other commodities, which may be re sold at cost ; and (3) 80,000,000*l* per annum representing the normal cost (1914-15 Budget) of our Army and Navy under peace conditions, the direct cost of the War to the United Kingdom may be put as follows :

	Direct Cost of War		Extra Revenue Raised		
			Income and Super Tax	Excise and Customs	Total
	£	£	£	£	£
4 months to end November 1914	100,000,000				
do. March 1915	180,000,000				
		280,000,000	12,800,000	6,000,000	18,200,000
do. July 1915	240,000,000				
do. Nov. 1915	280,000,000				
do. March 1916 (armistice period)	150,000,000				
		670,000,000	46,400,000	20,200,000	61,800,000
Interest on War Debt to March 31, 1916		50,000,000	—	—	—
		£1,000,000,000	£59,200,000	£26,200,000	£80,000,000

'The extra revenue raised is judged by comparing the actual revenue of 1914-15 and the Budget for 1915-16 with the first Budget (prepared under peace conditions) for 1914-15. The figures of the Budget for 1915-16 are taken notwithstanding the dropping of the increased beer, spirit, and wine duties included in it, since the revenue from these sources is not likely to be affected ; indeed, Lord Lansdowne gave figures in the House of Lords on July 6 indicating that a higher revenue than that assumed in the Budget will be received. The total

of extra revenue shown (which includes non-tax revenue) is lower than the sum of the two previous columns because of loss of other revenue, particularly from stamps. The foregoing table shows that, on the assumptions made, only some 8 per cent. of the direct cost of the War will have been raised by increased revenue during the sixteen months from December 1, 1914, to March 31 next, and indeed only 6½ per cent. if the cost of after-War pensions and allowances is also taken into account.

'Apart from Treasury Bills and the meagre amount of increased taxation, the cost of the War is being raised on two War Loans. The 3½ per cent. War Loan realised 331,000,000*l.* net. The new 4½ per cent. War Loan has realised a little over 600,000,000*l.* Pending definite figures as to conversions of old loans (which cannot be known till November), a forecast of the Treasury of June 21 may be adopted. According to this forecast, 250,000,000*l.* of Consols and 200,000,000*l.* of the War Loan 1925-28 may be converted, leading, with the 600,000,000*l.* of new money, to the following result:

——	New Stock received on conversion	New Subscriptions	Total of New Stock issued
	£	£	£
To holders of Consols . .	167,000,000	333,000,000	500,000,000
To holders of War Loan 1925–28	200,000,000	210,000,000	400,000,000
Subscriptions apart from conversions	—	57,000,000	57,000,000
	£367,000,000	£600,000,000	£957,000,000

'This would mean that the assumed cost of the War will (with the exceptions already given) have been raised as follows:

Proceeds of 350,000,000*l.* War Loan 1925–28	£331,000,000
,, War Loan 1925–45	600,000,000
Raised out of revenue in the fiscal years 1914–15 and 1915–16 . .	80,000,000
	£1,011,000,000

'Assuming for the moment that no further increased taxation comes into force before April next, the picture of the National Debt would be about as follows:

——	Nominal Amount	Interest per Annum
	£	£
4½ per cent. War Loan 1925–45 .	957,000,000	43,000,000
3½ per cent. War Loan 1925–28 .	150,000,000	5,000,000
Old National Debt (mainly 2½ per cent. Consols)	390,000,000	12,000,000
Total, say	£1,500,000,000	£60,000,000

'This means an increase of 860,000,000*l.* in the National Debt. Of the 1,500,000,000*l.* rather over 1,100,000,000*l.* will be redeemable, while practically all of the old National Debt of 640,000,000*l.* was irredeemable and subject only to purchase in the market, though there was also the alternative of redemption in each conversion scheme. The higher rates of interest on the War Loans will continue until at least 1925, when the 4½ per cent. Loan may be converted at a lower rate of interest. Assuming the 1,100,000,000*l.* of redeemable debt is redeemed by a Sinking Fund of a fixed annual amount for interest and redemption combined, the annual service would be raised from 48,000,000*l.* to 55,000,000*l.* if the period of redemption is spread over fifty years. This means

a total service, including interest and Sinking Fund of the old debt, of, say, 70,000,000*l.*, or, better, 75,000,000*l.* per annum, which compares with 25,000,000*l.* to 30,000,000*l.* in the few years preceding 1914-15. To this must be added the cost of after-war pensions and allowances, say 15,000,000*l.* per annum.

'Some idea of what this means can be gathered by comparing the actual figures for the national revenue and expenditure of 1907-08 (*i.e.*, before the Super-tax, Old Age Pensions, and National Insurance were introduced, and when income tax was 1*s.* in the pound), the first Budget of 1914-15 (representing normal peace figures and including a proposed income tax rate of 1*s.* 4*d.* in the pound), and a year after the War, the last-mentioned reckoned on normal taxation only :

—	1907-08 Actual	1914-15 Budget	A year in the near future[32]
Expenditure.	£	£	£
Army and Navy	58,200,000	80,400,000	100,000,000
National Debt Service	29,500,000	23,500,000	75,000,000
War Pensions and Allowances	—	—	15,000,000
Social Programme (Old-Age Pensions and National Insurance)	—	21,000,000	25,000,000
Education and other Civil Services	35,400,000	42,500,000	50,000,000
Post Office, &c.	28,700,000	37,600,000	40,000,000
Total Expenditure	£151,800,000	£205,000,000	£305,000,000
Revenue.			
Income (and Super) Tax	£32,400,000	£56,600,000	£40,000,000
Estate Duties	19,100,000	28,800,000	25,000,000
Stamps, Land Tax, House Duty, &c.	10,600,000	13,300,000	10,000,000
Total Direct Taxation	£62,100,000	£98,700,000	£75,000,000
Customs and Excise	68,200,000	75,000,000	75,000,000
Total Taxation	£130,300,000	£173,700,000	£150,000,000
Post Office and other non-tax Revenue	26,200,000	34,800,000	30,000,000
Total Revenue	£156,500,000	£208,500,000	£180,000,000

'The figures in the last column are set down to give a picture of what in all probability will have to be faced. They are based on a normal peace basis a few years hence. Neither a reduction of armaments nor the adoption of Universal Military Service is assumed, but just the normal increase of 4,000,000*l.* per annum for the Army and Navy to which we became accustomed before the War. The principal income-tax rate is taken at 1*s.* 2*d.* in the pound, being the general rate ruling for some years before the War, and the other revenue items are based on present taxation and on the assumption that the reduction caused by the after-effects of the War will be moderate. Thus, on figures which are moderately estimated and which may easily prove too favourable, there will—on the basis of normal taxation and a normal income tax of 1*s.* 2*d.*—be an annual deficit of 125,000,000*l.* on an expenditure of 305,000,000*l.*, and half of this deficit will be due to the increased debt service plus pensions and allow-

[32] EDITOR'S NOTE.—For these figures Mr. Kitchin accepts sole responsibility.

ances. A deficit of 125,000,000*l.* would mean that taxation would have to be increased to 275,000,000*l.*, *i.e.* by 58 per cent., over the 173,700,000*l.* of the 1914-15 Budget. This result, it may be well to reiterate, is based on the assumption that hostilities will come to an end after sixteen months of war, and the 200,000,000*l.* or so to be lent to our Allies and the Dominions is also ignored. If the War lasts beyond November—and any Chancellor of the Exchequer must budget for its doing so—the burden to be faced will be still higher.

'The following figures, which can only pretend to be very rough, contrast the assumed financial result to the United Kingdom of the present War with that of earlier wars:

——	Napoleonic Wars, 1793-1815[33]	Crimean War, 1854-1856	Boer War, 1899-1902	Present War, 1914- ? (Estimated)
Direct cost of war to United Kingdom	£831,000,000	£67,500,000	£211,000,000	£1,000,000,000
Raised by National Debt	£440,000,000	£32,000,000	£143,000,000	£920,000,000
Proportion . . .	53%	47½%	68%	92%
Proportion raised out of revenue during war	47%	52½%	32%	8%
Portion of cost raised annually out of revenue during war	£19,500,000	£13,500,000	£25.000,000	£48,000,000
Annual Debt service per head per annum before and after war	13/0–35/0	22/0–23/0	11/6–13/6	10/6–31/9
Annual taxation per head per annum before and after war	20/0–70/0	42/0–48/0	44/3–55/6	75/6–116/-
National income per annum before and after war	£250–£350 millions	£500–£550 millions	£1600–£1800 millions	£2250 millions
Proportion of National income paid in taxes before and after war	6%–20%	11%–12%	5½%–6½%	7¼%–12¼%

'The proportion at present raised out of taxation (most of it merely covering current interest on War Loans) is far lower than in previous wars, but this is perhaps not a fair way of looking at the matter, as the amount it is possible to raise out of revenue must be proportioned, not to the cost of the War so much as to national income. The last line in the foregoing table is therefore the one of most significance. Obviously, we should be able to pay in taxes a higher proportion in respect of present income of 2,250,000,000*l.* per annum (49*l.* a head) than could our forefathers in respect of their income of a hundred and twenty and a hundred years ago of 250,000,000*l.* to 350,000,000*l.* per annum (17*l.* or 18*l.* a head).

'It is not feasible to fix a definite proportion between the amount which should be borrowed for the War and the amount which should be raised by taxation, and it is probably more a matter of first incurring debt and then paying it off rapidly than of meeting a substantial portion of the cost of the War otherwise than by loan. The extra revenue now being raised (61,800,000*l.* per annum) is insufficient even to meet the estimated increased cost in future of the National Debt plus pensions and allowances (68,500,000*l.* per annum), and thus in effect we are momentarily raising nothing to meet the direct cost of the War. Though we cannot hope, unless the War lasts an appreciable time longer, to meet any great proportion of the cost of the War while it continues, that is no

[33] Professor Bastable does not accept these figures for the Napoleonic Wars, see p. 612.

reason for not raising all the position permits, and that at once. To borrow instead of taxing now does not pay for the cost of the War, but means that the payment is left to be made with usury for many long years after the War is over. The more is borrowed, and the longer the borrowing lasts, the heavier the taxation to be faced in the future. The taxation of 275,000,000*l.* per annum (suggested as necessary a few years after the War if the present method of borrowing virtually all the cost is continued) will be much heavier if hostilities last beyond November. In any case the present taxation of 235,700,000*l.* (budget figure for 1915-16) is much below that figure, when beyond question it should already be much above it. Twenty per cent. of our normal national income would be 450,000,000*l.*, but there are obviously considerable difficulties in raising such a sum while war goes on, for in practice it involves devising new means of taxation, a further increase in the income tax (if its basis is not considerably broadened) being quite insufficient to provide the amount.

'For a time after the War there is likely to be a period of abnormal prosperity, and after that a time of depression is to be anticipated. The first period is put by Mr. Lloyd George at four or five years, but there is too much reason to fear it may be much shorter—say two or three years. Thus the greatest chance of lessening the burden which the War will leave behind it is to be found in the two or three years after peace is declared. It stands to reason that the time to tax heavily and to relieve posterity is much more the time when savings are high by reason of private economies and special war income than when the inevitable period of depression has come, hence taxation should be increased at once and maintained at as great a height as the position will stand, so that some relief may come when it is needed. We have in the United States a good example to follow. After the costly Civil War of 1861-65, the war taxation was unflinchingly kept up until the National Debt was sensibly reduced Between 1865 and 1880, the Federal Debt fell from 570,000,000*l* to 400,000,000*l*, in 1881 the Government was able to re-borrow at 3½ per cent., and by 1887 the debt was reduced to one-half of its maximum figure. The adoption of this policy did much to assist in the remarkable recovery of that great country. If we can follow that example and reduce our War Debt to one-half in twenty-two years we should certainly do so.

'The United Kingdom will probably emerge from this War in a better position than any of the other belligerent countries, none of which seems to be meeting any part of the cost of the War or interest on War Loans out of current revenue. Germany had a pre-War debt of 1,040,000,000*l.*, but it was not an almost entirely unproductive debt like ours, for it is fully represented by the value of its State railways, mines, lands, and forests. It is likely to have in addition a War Debt of 1,500,000,000*l.*, the annual service of which should approximate to 85,000,000*l.* We have the advantage of the other belligerents, because we are the richest of the countries at war, are more free from disturbance to trade, and have suffered no devastation; but the War will certainly put us in a disadvantageous position as compared with the United States, which will therefore have the after-War cream, while we shall have to be content with milk, and the other belligerents with skim-milk.'

Professor Dicksee and Mr. F. W. Hirst believe that the nation is better able to bear heavy taxation during a war than during the years immediately following the conclusion of peace, although the Professor assumes that the taxation is 'intelligently applied, so as to hit those who are benefiting financially from the war.' Professor Boyd Dawkins also writes in support of immediate taxation, and urges that special imposts should be levied upon war profits. Sir Edward Brabrook is inclined to recommend further taxation, but regards the question as one of the greatest difficulty: 'The test of the propriety of taxation is the ability of the community to bear it, *i.e.*, to bear it without sacrificing all that makes life endurable.'

The views of Mr. D. M. Mason coincide in the main with those which we quote later from Professor Bastable. While saying that no *fixed* proportion can be laid down, he would raise as much as possible by taxation. 'The advantages of taxation,' he writes, 'as compared with borrowing consist in this, that taxation comes home more directly to all sections of the community. This fact tends to direct men's minds to the necessity of bringing the War to a close as soon as possible. Loans, on the other hand, deceive the general community by

creating for the time being apparently great prosperity with comparatively small hardship. This is brought about by the expenditure of the proceeds of the loans without corresponding high taxation. Another great evil resulting from large loan expenditure is that the added stimulus due to the expenditure creates an abnormal demand for labour. After the war there is a great influx of labour seeking employment and a diminished supply of capital. The result is a great deal of unemployment and misery for the working classes. While loans are, no doubt, necessary for the carrying on of a great war, regard should be given to the state of the money market at home and abroad both before and during the continuance of the War. It is also imperative in time of peace, particularly if there is any probability of war, to practise economy and keep down taxation with a view to a financial reserve for war when it comes.'

Mr. Gibson agrees with Mr. Kitchin's view that the best time for materially increased taxation is in the few years immediately after the declaration of peace, but not with the view that a period of depression is a bad time for it. 'Trade depression,' Mr. Gibson continues, 'is just the time when people have large liquid resources, savings are high owing to the reduced cost of living, and investment prices rise through the increased demand for investment. Manufacturers require their liquid capital in times of trade booms, but not so much in times of depression. Increased taxation from a national standpoint can be better borne in a time of trade depression than in a time of activity and rising prices.' From the banker's point of view this is so, for depression always liberates a part of the working capital of many firms which goes temporarily to swell bankers' balances But such moneys are not easily reached by taxation, and, if they were, the burden would be felt when trade revived through an added scarcity of capital.

Professor Dicksee agrees with other correspondents in holding that 'public economy in time of peace is the best possible way of providing a financial reserve against time of war.' He continues: 'At the risk of embarking upon political rather than economic issues, I should like to put forward the view that we are now being called upon to pay for the experiments of politicians in social reform during the past ten years. The need for both public and private economy is fairly obvious; but public economy has been rendered difficult by the enormous increase in the number of officials employed by Government Departments and local authorities, while private economy is rendered difficult by the heavy taxation—even on a peace footing—of the well-to-do classes, and by the general trend of legislation which seems to have been specially designed to discourage thrift.' Referring to Mr. Ellinger's suggestion, Professor Dicksee continues: 'I agree that, whatever opinions may be held on the subject of so-called tariff reform, the taxation of imports seems desirable under present conditions, and that, while it may be impossible to foretell whether the effect would be to discourage imports or to produce a revenue, the consequences would be equally desirable in either event. There seems, however, some confusion of thought about the suggestion that an excessive income-tax would be undesirable as reducing the amount available for subscription to Government Loans. From the Government point of view, the revenue derived from taxation (of whatsoever kind) is clear gain; whereas Loans call for ultimate repayment, and in the meantime have to carry interest. Accordingly, even supposing the effect anticipated by Mr. Ellinger were in fact produced, the result would not be disadvantageous to the Government, however inconvenient it might be to individuals.'

Here we cannot agree entirely with Professor Dicksee's views. If income-tax or estate duties—or indeed direct taxation generally—is made too heavy, the yield declines proportionately and might even decline absolutely. It cannot be said in advance when an increase in direct taxation would cease to be productive beyond the general *caveat* that there is such a point. Allowance must be made for psychological conditions. At the moment patriotism would make that limit recede, but as the dangers of war become more remote this influence grows less effective; thus the psychological influence is an argument for early taxation.

Professor Bastable, who has composed his memorandum after reading those written by the other contributors, thinks that the proportion of the tax contribution to the wars of 1793-1815 has been over-estimated. 'Instead,' he

writes, 'of one-half of the cost having been met by taxation, the fact seems to be that little more than one-fourth of the war expenditure was so provided. If the total cost of the war be taken as 830,000,000*l.*, the contribution from loans was 600,000,000*l.*, and that from taxation 230,000,000*l.* It must, however, be said that the borrowing took place chiefly in the period from 1793 to 1800, and that much greater efforts were made to secure an adequate tax revenue in the later years of the war. There can be no doubt that Pitt's policy in respect to war finance was affected by two influences, viz. (1) the fear of popular hostility to heavy taxation, and (2) the belief in the magical operation of the sinking-fund scheme. We have to recognise that earlier use of the income tax would have greatly lightened the financial strain and the accumulation of debt. The financial management of the Crimean War (which was more in the hands of Cornewall Lewis than in those of Gladstone) was more satisfactory. More than half of the cost was met out of tax revenue (38,000,000*l.* out of the total of 70,000,000*l.*), which showed a marked contrast with the French policy in the same war.'

The consideration of the above facts has more than a mere historical interest, and we wish to call special attention to the grave warning of Professor Bastable in the following paragraphs. It is obvious, as he justly says, that 'the great lesson to be derived from them is the need of immediate adjustment of the financial system on the outbreak of war. The easy course of borrowing is open to the conclusive objection that it mortgages resources that will soon be needed, while it induces the ordinary citizen to think that he is not called on for any additional effort. But in no previous case has the necessity for this adjustment been so great as in the present war. Though Pitt bequeathed a heavy burden to the British taxpayer of the nineteenth century, the immense development of British industry as the result of the manufacturing system and colonial expansion furnished a counterbalancing force. It is not within the range of reasonable probability to hope for anything similar in the twentieth century. Moreover, the call on the "national dividend" is proportionally greater. At no time in the course of the Napoleonic War did the borrowings of the State absorb the whole savings of the country. The present rate of war expenditure exceeds threefold the annual savings of the United Kingdom in peace time. The necessary consequence is that there must be either a great growth of "net," as distinguished from "gross" income or that assistance must be obtained from the disposable funds of other countries. To secure the former there will have to be effective inducements to saving in the form of high interest, or compulsory additions to the net revenue forced by the pressure (what Mill somewhere calls "the whip and spur") of taxation.

'On these plain and simple grounds rests the general rule that a great war calls for (1) a large development of existing forms of taxation and (2) the adoption of any new and feasible forms. Whatever may be said in respect to times of peace, it is certain that productiveness is the one great criterion of war taxes. The nice distinctions of charges on income, on property, on commodities, or on expenditure in general, as well as the problems of just distribution, have to yield to the fundamental consideration of the best way to obtain the maximum return. The only other element of importance is the effect of the tax methods on the productive power of the country, which is itself a branch of future fiscal productiveness. Controversy as to the respective merits of different forms of taxation is really excluded by the urgent necessity of employing *every* effective method. It follows, therefore, that heavily increased taxation of income, especially unearned income (for this is in fact a property tax), much higher rates of duties on fiscally productive commodities, and the increase of any minor duties that are likely to prove fruitful should be speedily brought into operation. Nothing but actual trial can show the limit to this use of taxation. We may, however, get some clue by considering the amount of the national income and the proportion that can be appropriated by the State in case of urgent need.

'If 2,000,000,000*l.* be taken as an under-estimate of the national income, and if we take the view of those financial writers who hold that under emergency pressure 25 per cent. of this income could be secured for the State, it follows that for a limited period of strain 500,000,000*l.* would be the available tax revenue. Bearing in mind the possibility of very large economies on the normal

peace outlay, it seems as if vigorous financial administration, sparing no special interests or classes, would supply over 300,000,000*l.* for each year of a limited war period. The tax revenue, just indicated as possible, has evidently to be supplemented by the use of loans. It is, or ought to be, recognised that there are large funds which cannot be brought in by the pressure of the tax-collector, but which will flow in to the Exchequer if the inducement of adequate interest is afforded. We may perhaps assume that by this means an amount equal to that gained from taxation is obtainable, year by year, for a war period of several years. The compulsory contribution of the taxpayer is balanced by the voluntary payments of the saving class.

'The general result of the foregoing estimate shows an annual fund of over 700,000,000*l.* available for the cost of war. Taking the total of this cost as approximating towards 1,000,000,000*l.*, there remains a sum of over 250,000,000*l.* to be supplied, and here the use of an external loan is manifestly prescribed. By adopting the sound policy of exempting the interest on such a loan from British taxation the raising of the required amount would be facilitated. In addition to the immediate financial relief there would be the important effect on the Foreign Exchanges (it need hardly be said that the United States would be the chief field of contribution) and the beneficial political bearing through the financial interests becoming attached to the side of the borrowing country. As the struggle proceeds, the need of some such arrangement will, I believe, become plainer; but delay will mean heavy financial loss and greater difficulty in bringing about the needed adjustments.'

We are inclined to think that with taxation of over 300,000,000*l.* more than 350,000,000*l.* could be raised by loan, even without trenching (as was done in the Napoleonic Wars with the result of a suspension of cash payments) upon those bankers' funds which should be kept liquid. But to do that we must call upon our reserve supply of labour and produce more goods, particularly for export. Therefore the nexus of ideas is public and private economy together with increased production; unless we accomplish the last, we are not making the most of our command of the sea. Probably if war expenditure does not exceed 1,000,000,000*l.* per annum this country could finance this almost altogether, if not altogether, by taxation and loan, but the national income would need not to fall below 2,000,000,000*l.*; we should have to take over 20 per cent. of that, and under the conditions indicated we could lend, say, 450,000,000*l.* per annum, possibly more. But the sacrifice involved in the marginal taxation would be extremely great and the marginal borrowings would be raised at a high cost, thus it would probably be cheaper on the whole to float external loans of moderate amounts. The problem is, in fact, whether there is a balance of advantage in obtaining the marginal 150,000,000*l.* or 200,000,000*l.* of annual war expenditure (in the event of a long war) from British or from external sources.

VI. *The War and the Foreign Exchanges.*

The inquiry into the effect of the War upon the Foreign Exchanges may conveniently be divided into two periods. The first of these covers the few weeks immediately succeeding the outbreak of war, when the exchanges throughout the world with hardly an exception suffered complete disorganisation, from which they gradually recovered as the first shock spent itself and emergency measures were taken to ameliorate the existing financial stress. The second period displays the gradual cumulative effect of war conditions and war expenditure upon the financial relations of each of the combatant nations with its Allies and with the principal neutral countries, an effect which in the case of this country has only now begun to attract serious attention.

With regard to the first period it is beyond doubt that if everyone had kept his head and had correctly gauged the future, the collapse of the exchange machinery could have been avoided. When we remember, however, that the outbreak of war took the financial world by surprise and that there were few precedents to guide men in such an emergency, it is not surprising that mistakes were made.

Two circumstances have contributed to make London the financial centre of the world: (1) it has been for generations the one absolutely free gold market, and (2) the Bank of England has always been willing to cash its notes

in gold to any extent, both for internal use and for export. Thus the 'exchange' of the whole world has centred round the sterling bill, which had come to be regarded, in Mr. Franklin's phrase, as actual 'interest-bearing gold.' Nearly every foreign State Bank was in the habit of keeping a certain portion of its reserve in sterling bills, which were renewed from time to time as they became due, and only 'melted' when and as these banks desired to replenish their stocks of gold. In practically every foreign country the rate of exchange on London is not reckoned by the value of the unit of currency of that country in pounds, shillings, and pence, but by the number of francs, marks, dollars, &c., necessary to purchase the pound sterling.

The outbreak of war found London the creditor of the world as regards short-dated obligations, and the hurried calling in of such obligations caused a stampede for sterling remittances, which rose to extraordinary prices. The normal rate in New York for London cable transfers is 4 86½ dollars the pound sterling, but in August last year rates of 6½ dollars were dealt in. In other centres it was impossible for a time to obtain sterling remittances at any price. Many countries forbade the export of gold; arbitrage operations, which in more normal times are used as a lever to redress variations from normal exchange rates, ceased altogether; the creation of finance bills stopped abruptly; the Stock Exchanges of the world were closed. Gradually, however, as men began to view the situation more calmly the confusion was allayed. Credits which had been abruptly recalled were in many cases renewed. Emergency measures which are described elsewhere helped to restore confidence. During the prolonged Bank Holiday, one of the most important problems before the Treasury was the re-establishment of foreign exchange, as it was recognised that, until this was accomplished, it would be quite impossible to carry on the foreign trade of this country. In order to do this, it was necessary in the first instance to re-establish the position of the sterling bill. For this, two things were necessary—the first to induce accepting houses to continue and grant legitimate trade credits, and the second to induce banks and discount houses to discount these acceptances when created. For the accepting houses realised that a large and unknown proportion of their acceptances would not be provided for by the drawers at due date, and the discount houses believed that many of the bills bearing their endorsements might not be met by the acceptors. Neither acceptors nor endorsers, therefore, felt themselves justified in adding to their liabilities. 'These two apparently insuperable difficulties,' Mr. Franklin writes, 'were overcome by the Treasury, with the assistance of the Bank of England, in a manner that will always be recognised as masterly.'

One of these measures had a curious and unexpected effect. The Moratorium enabled foreign customers to postpone the transfer of the sterling to London. 'There is no doubt,' Mr. E. F. Davies writes, 'that the Moratorium saved enormous sums to foreign countries which were indebted to London, and it also arrested the tremendous rise that was taking place in the foreign exchanges in favour of this country. The following table shows the rates of exchange current immediately prior to the War and the highest and lowest quotations since:

	Rate just before War	First year of War	
		Lowest	Highest
Paris	25.18	24.00	27.60
Amsterdam	12.14	11.70	12.60
Switzerland	25.18	24.00	26.40
Italy	25.30	24.00	29.45
Madrid	26 15	23 85	26.60
Petrograd	96·10	105.00	160.00
Scandinavia	18.25	18.02	19.70
New York	4.88½	4.76	6.50
Rio Janeiro 90 d/s	16*d.*	11¾*d.*	nom. 14 7/16
Buenos Aires 90 d/s	47¾*d.*	46 5/8*d.*	49*d.*

The remarkable jump in the American exchange was due firstly to the general causes already mentioned, and secondly, as Mr. Davies points out, to the fact that the city of New York found itself obliged to pay off 13,500,000*l.* sterling short notes maturing in this country at that time. There is no doubt that it would have been a very profitable transaction for English bankers to have renewed those notes, and to have thus kept a certain control over the exchange, but, owing to the manner in which the renewal at that time was proposed, the operation did not meet with general approbation. It would have relieved the situation if the notes had been renewed here, and it would have been a very remunerative investment for anyone foresighted enough to purchase the issue of yearly dollar bills with the exchange round about six to six and a-half dollars and the return that the interest gave them in New York. The action of the Government in stepping in and adjusting the rate of exchange was no doubt good at the time, because it had the effect of restoring normality, although everyone should have known that this country and her Allies would have to buy enormously in the United States of America, which would quickly reduce the exchange rate to its normal level.

Before turning to the second of the periods into which our subject is divided a few words of explanation are needed. Mr. Metz[34] divides the influences which determine the level of exchange rates into four heads, as follows:

(*a*) Trade balance, including trade in securities.
(*b*) Service balance, including interest as remuneration for the service of lending money; in other words, interest on foreign debt held.
(*c*) Gold shipments.
(*d*) Credits abroad.

A fifth may be added in some cases, viz., the depreciation of the internal currency of a country, which is reflected in exchange rates between that country and others; and (*b*) should be interpreted to include the services of our shipping, in which the rise of freights balances, to some extent, the diversion of merchant ships to war purposes.

In normal times (*a*) and (*b*) are of primary importance, and (*c*) and (*d*) are chiefly used to redress temporary fluctuations in the volume of (*a*) and (*b*). In times of peace (*a*) and (*b*) tend to an equilibrium or are brought to an equilibrium by the operation of a steady accumulation of foreign investments or foreign indebtedness, according as the nation is an investing country such as the United Kingdom, or a spending country such as our Dominions and Colonies, which are yet in process of development.

The effect of a war such as the present is, however, to disorganise the normal balance of trade and service. Every combatant is compelled to import enormous quantities of war material and food, whilst its own power of production is necessarily seriously impaired by the withdrawal of masses of men from productive enterprise for military purposes. This process is in operation in the case of all the nations now at war, though in the case of some of them it is modified or complicated by the military and naval operations of their opponents which have restricted foreign trade to its narrowest limits. The result is that the belligerents' imports overshadow their exports, and the rate of exchange tends more and more against such countries and in favour of the principal neutral nations.

Thus in Germany the premium on dollars had risen in July 1915 to about 17½ per cent., the Amsterdam rate showing a similar percentage against Germany. In England exchange rates with neutral countries were irregular, but in no case was the premium more than 3 per cent. In France at the same date Dutch currency stood at about 8½ per cent. premium. In Russia sterling exchange had reached a premium of 54½ per cent., and the Dutch exchange a premium of 58¾ per cent. In Amsterdam the Austrian currency stood at a depreciation of 25 per cent., and the Italian of nearly 18 per cent.

What is the significance of these figures? To what extent do they denote

[34] Mr. S. Metz, who writes from Amsterdam, the chief neutral financial centre, has furnished the Conference with most useful information on the exchanges.

merely a hitch in the machinery of remitting money, and how far if at all are they evidence of a depreciation in the value of each country's currency?

None of the belligerents will admit such a depreciation, though few impartial observers, if such can be found, will deny its existence. As regards the English currency, the argument will probably be used that, unlike all the other belligerents, gold is in free circulation, and that its export is not prohibited. But, as Mr. E. L. Franklin points out, 'at the present time, notwithstanding that there is no prohibition placed on the export of gold to neutral countries, no bank or banker can be found who will avail himself of the benefits accruing from such transactions, because it is the general opinion, whether justified or not I will not say, that it is against the interests of this country for gold to leave England so long as other Governments do not allow gold exports from their countries.'

The creation of credit has been necessarily profuse, one might almost say necessarily reckless, in this country during the War; wages and prices are on a war basis which can admittedly be only temporary. The result is inflation, which in the opinion of many is reflected in an unfavourable rate of exchange. What is to be the remedy? Let us turn back to our summary of the factors which determine the level of exchange rates From these we may dismiss (*b*) as a potential lever for influencing the rates between this country and others The interest on debts due from abroad will certainly decline rather than increase during the War, and the withdrawal of men from industry for military purposes prevents any increase in the volume of our services to other nations. The shipment of gold provides a possible palliative for an unfavourable rate, and the criticism is often heard that gold reserves are valueless unless use is made of them. In the present case, however, we are confronted with the difficulty that our stock of gold is wholly inadequate to maintain exchange rates, and that America, to which country most of the gold exported would find its way, has ample supplies of the metal. Mr. Metz, indeed, argues that the export of gold, the sale of securities, and the creation of credits all 'suffer from the same evil, that they can be applied only once, and that, once availed of, they weaken rather than strengthen the situation.' Mr. Davies, on the other hand, can see only one practical way in which this exchange can be rectified, and that is by 'the issue in the States of a large loan, free of income tax, for account of Great Britain There is not the slightest doubt, in view of American public opinion on Germany's submarine warfare, and the extremely favourable rate of exchange for American investors, that the United States would have subscribed largely to the recent British War Loan, had it not been for one factor, viz., that no provision was made in the terms of the issue to exempt foreign subscribers from the British income-tax'

Gold exports, therefore, cannot be relied upon as a permanent way out of our difficulty, and the loss of our small stock might have serious results in weakening confidence both here and abroad. There remain to us (*a*) and (*d*). The trade balance may be permanently affected by the discouragement of imports into this country, by the encouragement of exports, by increased economy of consumption, and by taxation. In speaking of imports and exports it may be noted that we are not speaking merely of the trade with the United States of America. Our trade is not and cannot be divided into compartments, and, though the present difficulty is the exchange rate with America, this rate can be directly influenced by trade transactions with other countries.

In all these directions something has been done by exhortation in the speeches of Cabinet Ministers and from the pulpit, but it may be doubted whether such exhortations have had any but the most superficial effect, nor are they likely to touch more than the fringe of the question. Action of a more direct kind is needed, and such action is not likely to meet with insuperable obstacles. Economy should be enforced as well as preached, and the lesson should be the easier in that Germany has already set an example to the whole world. But when all these palliatives and remedies have been adopted there is little doubt that there will remain a great deal to be done, and our weapon for this purpose must be the raising of credits abroad. Here again the difficulties are merely difficulties of detail and procedure, for no one doubts that the British Government could raise money in the United States on favourable terms.

APPENDIX.

The Third War Loan. By D. DRUMMOND FRASER, *M.Com.*

Is another War Loan necessary? In the event of the continuance of the War till the end of the current financial year our expenditure will exceed our revenue by not less than 1,000,000,000*l.* Towards this the second War Loan is raising 600,000,000*l.* To be able to borrow on such a colossal scale the Government must dominate and attract the savings of the people. The bulk of the proceeds of this borrowing—four-fifths—is expended in this country. Such a vast expenditure stimulates trade. This enlarges the national income and increases the savings of the people. A Government compulsory loan would intensify the savings by a forced reduction of expenditure, especially with regard to some of our imports. It must be remembered that it is as vital a necessity to reduce our imports as it is to increase our exports.

I suggest that the Government should adopt the banking principle of borrowing *day by day* directly from the people, in a simple and popular form. I propose the issue of Treasury War Bonds in three forms: repayable in three, five, seven, or ten years, at a fixed rate of interest payable half-yearly; the interest for the first half-year to be calculated from the date of investment to the end of the first half-year; a provision to be made on the back of the bonds for a transfer and a new bond to be issued when the transfer is completed.

1. A Treasury War Bond for 1,000*l.* or any multiple thereof.
2. A Treasury War Bond for 100*l.* or any multiple thereof payable in ten monthly instalments.
3. A Treasury War Bond for 5*l.* or any multiple thereof—scrip vouchers of 5*s.*, 10*s.*, and 1*l.* to the amount of 5*l.* or any multiple of 5*l.*, to be accepted as well as cash; holders of bonds not exceeding 100*l.* to receive their interest each half-year without deduction of tax.

In the national interest it is of the utmost importance that the Treasury War Bonds should be taken up by the people direct. It is notorious that the antiquated system of the other two loans, with their 'short-time' limit for application and payment, has not attracted the bulk of the people; and, in consequence, the banks have subscribed for a considerable portion of the two War Loans. This, after all, is the money of the people once removed. The bankers' real function is to be the custodian of the people's cash resources—deposits; 60 per cent. of which is employed to liquefy the people's 'quick assets'—bills and advances—which fructifies wealth. The bankers should only finance the Government temporarily through Treasury Bills over the counter, maturing three, six, nine, or twelve months after date [35]

To the timid banker who sees a dangerous competitor in the Government, I would say that, in spite of the fact that during the first ten months of the War the Government had raised 600,000,000*l.* from the first War Loan, Exchequer Bonds, and Treasury Bills, the deposits of the banks had actually increased in the same period 200,000,000*l.* I would remind him that since the banks have taken their branches to the homes of the people, the deposits during the present generation have increased 200 per cent. I would further remind him that the business of the country is conducted with an incredible smoothness through the bankers' clearing houses by means of the crossed cheques, the daily average number of which exceeds one million. It was Gladstone who first freed the cheque from its legal disabilities. He was warned by the timid banker of his day that he was placing a very dangerous weapon in the hands of the people. The municipal corporations, the Lancashire cotton mills, &c., have already educated the people with undoubted success in the banking principle of borrowing money day by day direct from the people, for short periods, at a fixed rate of interest. If the bankers, brokers, and financial houses act for the Bank of England, on behalf of the Government, in receiving applications for the Treasury War Bonds, and also in repaying or renewing them, then the Government could obtain the necessary money, when needed, by recurrent popular advertisements in the daily press.

[35] Mr. A. H. Gibson supports this proposal.

In the course of the Discussion the following Paper was read :—

The Effect of the War on Finance and Currency. By YVES GUYOT.

War represents an excess of consumption; the belligerents consume capital under every form; nothing remains of it. No doubt the men who are at the Front would have been obliged to consume in time of peace. But they would certainly have made more economical consumption; moreover, most of them would have been busy supplying agricultural or industrial goods, or by transport, by trade, or by banking operations they would have been useful to the economical repartition of those products.

The said products do not exist. The saving power has therefore been almost entirely destroyed. Only those who have been producing for the large consumers—namely, the belligerent nations—have been able to put aside a part of their profits, a much smaller part than is supposed, at any rate in France and the United Kingdom; those are the only amounts of capital constituted since the War.

No doubt the subscribers to Loans will receive higher interest than they would have received if the War had not given rise to the enormous needs of the States; but as the States will be obliged to saddle the mass of taxpayers with further burdens in order to pay interests and clear off the Loans, the result will be an extra charge on the general expenses of each inhabitant of the land.

Thus, on the morrow of the War: destruction of an enormous mass of fixed capital which will have to be reconstituted; railroads, working plant worn out, not kept in order or not renewed, houses to reconstruct, and lack of available moneys. The needs will be great, but the purchasing power will be small, and the cost price will be increased by the higher rate of capital, the difficulties of procuring working plant and instruments, the scarcity of labour and fiscal surcharges.

The only means of repairing losses and increasing the economic power of a nation is the increase of the intensity of production.

It may be obtained by new inventions or discoveries, by a better division of labour; but any measure having for consequence a decrease of the efficiency of labour annihilates entirely or partially the technical progresses and increases cost prices.

If legislative or fiscal measures interfere with capital, they merely cause it to steer away from industrial enterprise and to abandon economic activity.

If, under pretext of protection, Customs duties increase the price of articles which the progress of industry, of banking, and of means of transport strive to lower, they increase the necessary effort for the acquisition of such articles, and consequently they lower the efficaciousness of technical improvements.

Many employees have been persuaded that by means of controlling measures exercised by State, by restrictions due to the trade unions, they could obtain higher salaries in return for a minimum of their productive capacity. It is necessary to look for means of giving the maximum of productive strength to labour on the following bases: harmony for the workman between his interests and professional morality.

Much has been said about private and public economy. Let the administrations set the example; we hope they will do so, though we confess that we have little faith to back such a hope. All the plans and projects laid down and discussed in the French Parliament concerning the economic future of France lead merely to an increase of expenditure. None aim at making important savings in the Budget previous to the War.

As for private economy, all is relative: no doubt there is a deal of useless waste, which it will be wise to diminish or to suppress; but economy is only a negative virtue, the intensity of production is a positive virtue, and it is on that virtue that we must build in order to ensure economic progress.

SATURDAY, SEPTEMBER 11.

The following Paper was read and discussed :—

Economic Problems after the War.

By the Ven. Archdeacon W. CUNNINGHAM, *F.B.A.*

There can be no accurate forecast of the conditions after the war; but as we have borrowed largely and spent the money unproductively, there is sure to be a heavy burden to fall on some one, though we cannot foresee exactly how it will be borne. We can only indicate hopes and fears as to the possibilities of the future.

During the war there has been an immense outburst of the sense of national duty; we may hope that men will continue to view the affairs of the country with public spirit, and that the *laissez faire* school which identifies national prosperity with the pursuit of private interests is dead.

There has been a great increase of governmental activity, and the experiments made in regard to the nationalisation of railways and the fixing of prices and profits and wages by the State are remarkable. They mark an increased sense of the nation as a unit, and indicate that cosmopolitanism has received a check. It is probable that each nation will be on the guard against the risk of being exploited by countries which are more advanced industrially. Great Britain was enabled by the age of invention to use her industrial superiority so as to control the resources of other countries; and though Great Britain has now left her Colonies free to pursue their own development, German organisation and her careful application of science to industry have given her the opportunity of pursuing the same policy.

It is of the highest importance that the problems of the increased burden caused by the war should be clearly stated; and there may be some misgiving lest the habit of mind which has been recently cultivated by English economists is the best for dealing with broad issues. Both consumption and production are necessary parts of the economic process, but the war has shown once more the importance of production—the production of munitions and the organisation of employment; the new school of economists, which gives an exaggerated importance to consumption and leaves production in the background, is not well fitted to deal with the questions. Many economists before the war took a short-sighted view of British interests, and helped to create the impression in Germany that Great Britain was so committed to neutrality that she would present no objection to the invasion of Belgium. By exaggerating the importance of consumption the same school of economists has given an apparently scientific basis to the claims of those who are taking advantage of the war to stand out for higher wages. In so far as the struggle at the Dardanelles has been due to political rather than military considerations they have laid undue stress on the possibility of importing corn from the Black Sea, and have raised the question as to whether cheapness to the consumer may not be obtained at too great a cost in lives.

The following Report was discussed :—

Report on Fatigue from the Economic Standpoint.—See Reports, p. 283.

SECTION G.—ENGINEERING.

PRESIDENT OF THE SECTION:—H. S. HELE-SHAW, D.Sc., LL.D., F.R.S.

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address:—

THE preparation and delivery of a Presidential Address is usually a pleasant and not difficult task, although it seems to be the custom mildly to intimate to the contrary. In ordinary times the President chooses a subject on which he has done some work, and with which he is therefore familiar, and with which, moreover, his name is more or less associated. If this had been an ordinary time, I should have liked to deal with the fascinating subject of mechanical locomotion, and to review what has taken place, let us say, since the meeting of the British Association held in Manchester rather more than half-a-century ago. The subject would have afforded ample scope, as we can realise by considering what would have been the effect produced if the distinguished Engineer, Sir William Fairbairn, who was President of the British Association in that year, had told his audience that within a comparatively short space of time our roads would be to a large extent occupied with self-propelled traffic; that electricity, then nothing but a toy, would play a most important part in our means of locomotion, not merely for driving but for lighting. That it would be used for searching out and communicating with vessels far away from the land and from each other; that ships many times the size of the largest ones then in ordinary use would employ steam as Hero employed it two thousand years ago, and obtain by this means a speed more than twice that of any existing ships; and that many ocean ships would be propelled against wind and tide by engines without using any steam at all. If the President had further proceeded to predict that ships would travel under water for long distances as easily as on the surface, and that, above all, a safe pathway would be found in the air by means of machines flying at speeds far exceeding that of the swiftest birds, I suspect he would have lost a good deal of his reputation as a man of judgment and common sense.

Such addresses, which deal with scientific progress, are most instructive, and the historical treatment of engineering questions is of the utmost value in assisting the judgment as to future possibilities. It is therefore most disappointing that I do not feel justified in taking up your time with an address of this kind.

The fact is, the time is not an ordinary one, for the war which a year ago cast its shadow over the Meeting of the British Association in Australia has, as the months have passed by, gradually unfolded the most terrible page in the history of the world.

It is terrible not merely because of the frightful slaughter which has taken place and which will yet take place, owing on one hand to the gigantic armies employed, and on the other to the nature of modern warfare. A predecessor in the Chair, one who has left many marks of his genius on the peaceful engineering works of the country, Mr. Hawksley, commented about fifty years ago on 'the unhappy necessity of devoting so much of the science and skill of members of the Association to the defence of the homes of the people of this great

nation.' He further remarked with great prophetic insight: 'War is no longer carried on by means of mere animal courage and brute force; on the contrary, we perceive, much to our amazement, I believe, that the highest branches of mechanical science and the most refined processes of the mechanical arts are resorted to by the modern warrior for the purposes of offence and defence. And we are taught by the logic of the facts that the modern soldier must cease to remain a passive machine, but on the contrary, must henceforth be trained as a skilled labourer, if not indeed as a skilled artisan.'

I do not think, however, that either Mr. Hawksley or anyone else could anticipate what refinements of skill and science would be brought to bear, not merely on the destruction of the human species but of those ancient edifices of beauty which cost hundreds of years to build, and which cannot be replaced, or even the loss of those great works of engineering in the form of bridges and other structures which, though doubtless replaceable, represent the accumulated wealth of mankind. All this does not constitute, however, the worst feature of the war which is still raging. I do not know which will hereafter stand out in the blackest light—the callous disregard by our enemy of the recognised laws which have governed warfare amongst civilised countries hitherto, of which the recent murder of a defenceless submarine crew in neutral waters is an example, or the fact, of which there is now abundant and overwhelming proof, that this country, while animated only by peaceful intentions, was itself the real object and ultimate aim for the destructive effort of our enemy.

Fortunately we now all know that our determination at any cost to ourselves to stand by our treaty obligation to a weaker country was really a fateful moment in the history of our Empire Had we then failed, such failure would have spelt our own doom.

This is not the place to dwell at any length on this subject; but I cannot help pointing out that the whole attitude of scientific and professional men in this country at the beginning of the war shows how little they realised the real nature of what was before us. Thus my own predecessor, after the war had begun, in his Presidential Address in Australia, used the words 'The discoveries in pure science, and their innumerable applications to practical ends, are ever a potent factor working for the common good.' The truth is that the great majority of us did not realise to what uses science would be put in the mutilation and destruction of our fellow creatures.

Still we are told by soldiers that practically any applications of science constitute legitimate warfare, and that the only way to escape from destruction ourselves is to employ all the resources of science in our own defence.

It is on these grounds that the Meeting of the British Association for the Advancement of Science has been held this year, because science is proving such an all-important factor in the present war

The mere holding of this meeting, however, with a vague sort of idea that science is associated with war, does not seem to most of us to meet the real needs of the case. The decision to hold the meeting was made in March, i.e., six months ago. Since that time the nation has awakened to the fact that matters have become very much more serious, and we scarcely needed the solemn warnings of our responsible statesmen to enable us to realise this. We see our foe turning every resource towards the active prosecution of the war, and bringing in the aid of every man towards that end. If the result were a small matter, we might pursue our way, as we did at first, with the fatuous cry, 'Business as usual'; but day by day it is brought home to us that the Hymn of Hate, childish though it may seem, really represents the serious mind and deadly intention of our enemy. When I say this I know there are exceptions, and it is gratifying to find that at least one German guest of the British Association acknowledged in print the generous manner in which the German guests were treated in Australia after the war broke out, even being given a passage home.[1] This and much else warns us that our failure in this war means the loss of what has been built up in so many centuries, and what we value above all other things, viz., our freedom, and that this loss would be accompanied by atrocities and degradation beyond the most savage happenings of the

[1] I regret to say this forms a striking contrast to the brutal treatment meted out in many cases to British visitors in Germany.

past. It behoves us all then who are members of it to show that the British Association, which has rendered such great services to the country in the past, can bear its share of the burden to-day.

I assume that we are all agreed upon this point, and it remains to consider the best way in which such a work can be carried out. Understanding from the President that he is dealing with the question from the point of view of the whole Association, I need only deal with the matter as far as it concerns our Section. After discussing the matter with our Secretary and several of my predecessors in the Chair, I suggest that we continue the three Research Committees already in existence, but do not institute a fresh one, forming instead a Special Committee, the purpose of which I propose to lay before you. Before doing this, I should like to point out that the very fact that engineering constitutes such an important feature of the War has prevented our having, as often in times past, papers on military and naval subjects, such as Warships, Armour, Projectiles, &c. And this for two reasons: first, because nearly every professional or manufacturing engineer having as a rule sent the best of his staff to the fighting line is overwhelmed by actual work either directly or indirectly connected with munitions and war material, and is much better so employed than in talking about the subject, or even in attending the present meeting; secondly, because men who really know all about such work would not be likely to discuss it in public at the present time,[2] and I am sure you will agree with me that we do not want merely popular science on war subjects.

Hence, the twenty-four papers before the Section deal with engineering science generally, but I venture to think they are of a high scientific quality, and quite as important in character as those of former years; and it will be noticed in several cases they touch closely on subjects bearing on the War, such as those on wireless telegraphy and traction.

The object of the proposed Committee is two-fold. The first of these would be to undertake any work which may be of use in an advisory capacity or by research, or indeed in any other way for direct assistance in the War. This would, of course, be a temporary object of the Committee, but nevertheless a real one, for, as stated by the Commander-in-Chief at the Front, this is a war of machinery; and a Cabinet Minister, in quoting this, quoted the further statement of Sir John French that it was not the German soldiers our men had to cope with; it was the artillery, ammunitions, and enormously powerful mechanical organisation of the German Army. I need not go into all that may be done in this direction by the Committee, but one step will be to place ourselves at the service of the Ministry of Munitions for such work. A certain number of the proposed Committee may be already doing munition work and also valuable work for other Committees with which they can at any rate keep us in touch; other members would be free to give all their time and service for such work as the opportunity presents itself.

With regard to the second purpose, the matter stands on a rather different footing. We were in many respects quite unprepared for the War on which we have entered, and though this offers one of the most powerful arguments in refutation of the charge that we deliberately entered the War for sinister purposes, it will be very disastrous if we repeat our unpreparedness when the War ceases, and we shall deserve the worst that can happen to us. When peace is concluded, it will only be a prelude to another war, and a war which will recommence with far greater energy on the part of our enemy than before—viz., the war of commerce—and the latter will be almost as serious for us as the more sanguinary one. This will be so even if we are victors, for as an historian (Professor Gardiner) has written: 'After a long war the difficulties of the victors are often greater than those of the conquered. The conquered have their attention directed to the reparation of losses and are inspired by a patriotic desire to submit to losses for the sake of their country. The victors are in the frame of mind which expects everything to be easy.'

Remembering how soon we forgot that black December week fifteen years ago; and the lurid indication from the German Emperor that he and his people had the will to destroy us then if not the power, and how swiftly

[2] I cannot help paying a tribute to the splendid work of the Economic Section, which Section does not suffer from our peculiar disability

we relapsed into national ease at the end of the Boer War, it behoves every man who can do so to take his share in making ready for the terrific struggle Germany is certain to put up in the arts and manufactures. I might give evidence of this from a number of sources, but I will only take one emanating from a body of Professors of the great Universities of Germany. These gentlemen have published a voluminous manifesto containing amongst other gems the following: 'Once the Russians are driven back beyond their new Frontier we shall not forget the war which England has made on the maritime and Colonial commerce of Germany. That must be the guide of our action and we must supplant the world trade of Great Britain. By her blockade of Germany, England has instructed us in the art of being a European Power, militarily, industrially independent of others. We must immediately seek to create for ourselves apart from the Empire of the Seas a Continental commercial enceinte as extensive as possible. . . . With regard to war indemnities, we shall demand an indemnity which as much as possible shall cover war expenditure, the repair of damage, and pensions for the disabled men, widows, and orphans. *We know that the question has been examined by the Government according to the financial capacities of our enemies.* From England, which has been so niggardly in men, we can never demand enough money, because England raised the world against us with gold. It is our duty to crush the insatiable cupidity of this nation.' It does not, however, want such published evidence to convince any practical person of the folly of thinking that a keen and virile nation having more than 100 million inhabitants is going to be crushed out of fierce and vengeful competition, whatever the end of the war may be. We shall better appreciate what this competition will mean if we consider the marvellous progress made by Germany during the last half-century in the arts and manufactures. Although we cannot say that this is absolutely measured by progress in the production of iron and steel, or even say that the corresponding rate of increase in production during that period by this country directly measures our progress relatively to Germany, still it does afford some indication in the case of the engineering industry Probably few of us have ever realised what I can show you by means of graphic curves of production of iron and steel For these curves I am indebted to the kindness of the Secretary of the Tariff Commission, who was good enough to prepare them specially for my Address, although I do not, of course, put them forward here as a tariff argument. The four diagrams, figs. 1, 2, 3, and 4, represent annual production in ordinates, and the corresponding years by abscissæ, the production of the United Kingdom being shown throughout in full lines and that of Germany by dotted lines. Taking first fig. 1, we have the actual production of pig iron for the last fifty years, and we can see at a glance the much more rapid rate of comparative production in Germany in recent years. When we come to the percentage relatively to the world's production, we see that while Germany is steadily rising, even in comparison with whole world output, the production of the United Kingdom is falling at an even more rapid rate than that of Germany is rising; for whereas fifty years ago it was more than half the production of the whole world, it is now only 13 per cent, whereas Germany's percentage, which fifty years ago was only 10 per cent., has now risen to 25 per cent. of the whole world production.

Figs. 3 and 4 tell the same tale, except that the relative production in steel of this country is now only 10 per cent., Germany keeping for many years the satisfactory figure of a quarter of the whole world's production; and it is of course quite familiar matter that, as far as science and discovery go, Germany owes her growth in steel production largely to the discoveries in this country, although in the case of the Bessemer steel process, she evaded the payment of royalties in making use of the invention. We know that the same tale is to be told in many other industries, such, for instance, as the chemical industry, and we are now suffering severely from the want of the very dyes which were invented by one of our own countrymen.

The above curves are quite sufficient to illustrate the marvellous progress of Germany; and in passing I may remark that one of the most persistent allegations which has been repeated *ad nauseam* by German statesmen, soldiers, professors, and the whole German press generally, is that the War is caused

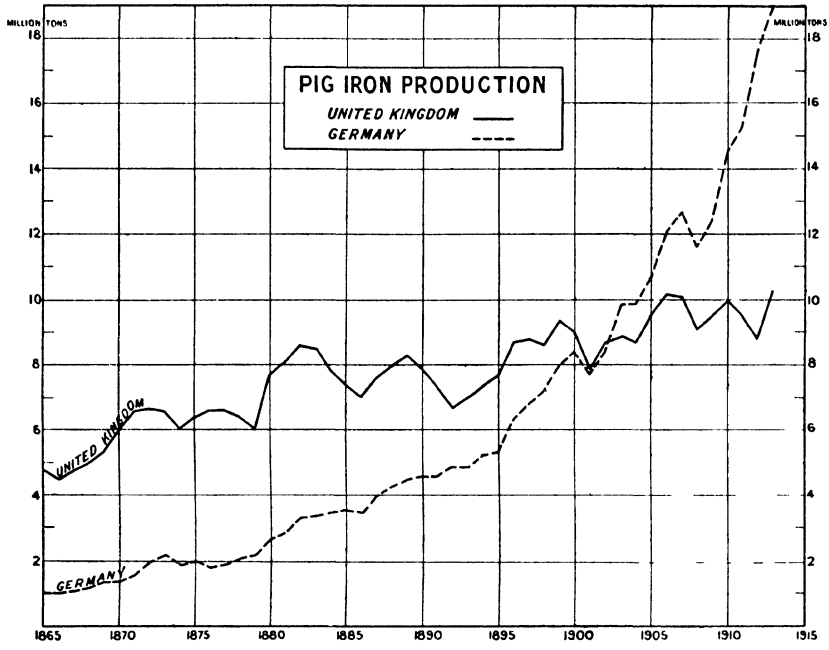

MILLION TONS
MILLION TONS
PIG IRON PRODUCTION
UNITED KINGDOM
GERMANY
UNITED KINGDOM
GERMANY
18
16
14
12
10
8
6
4
2
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915

Fig. 1.

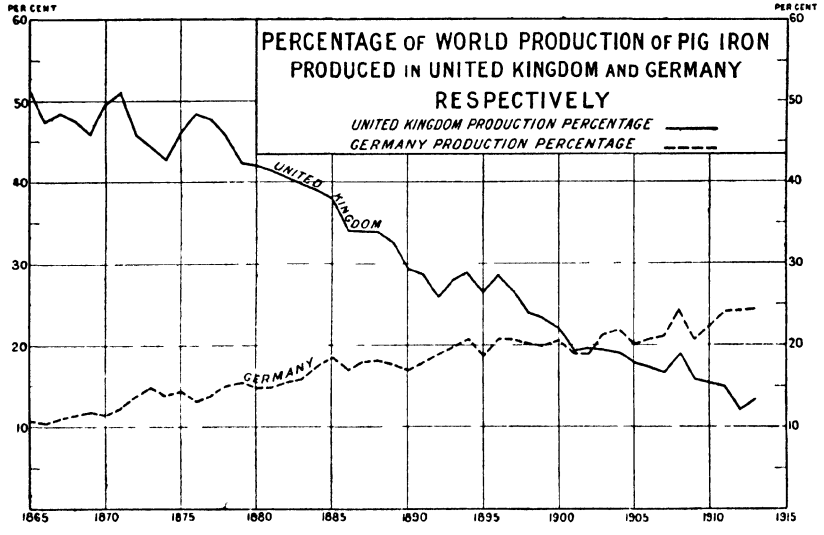

PER CENT
PER CENT
PERCENTAGE OF WORLD PRODUCTION OF PIG IRON PRODUCED IN UNITED KINGDOM AND GERMANY RESPECTIVELY
UNITED KINGDOM PRODUCTION PERCENTAGE
GERMANY PRODUCTION PERCENTAGE
UNITED KINGDOM
GERMANY
60
50
40
30
20
10
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915

Fig. 2.

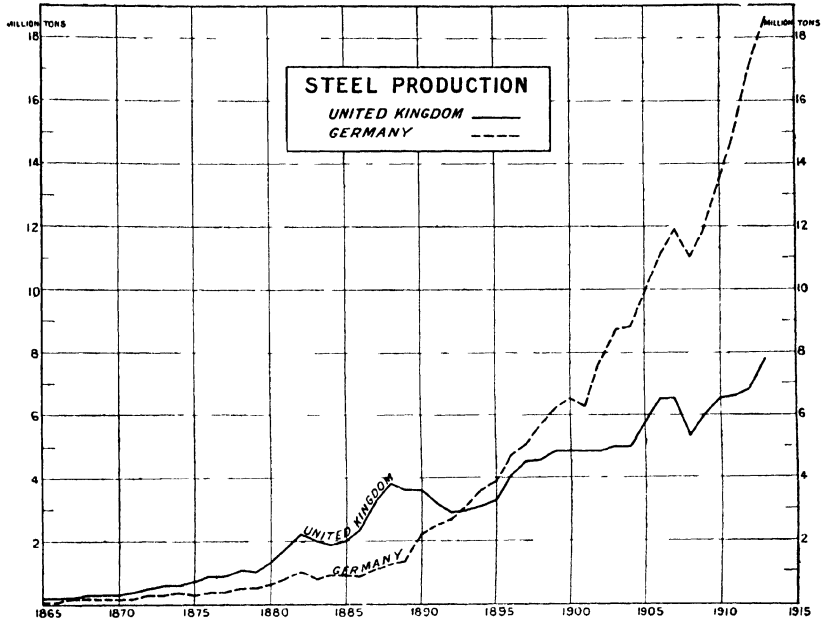

STEEL PRODUCTION
UNITED KINGDOM
GERMANY
MILLION TONS
UNITED KINGDOM
GERMANY
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915

FIG. 3.

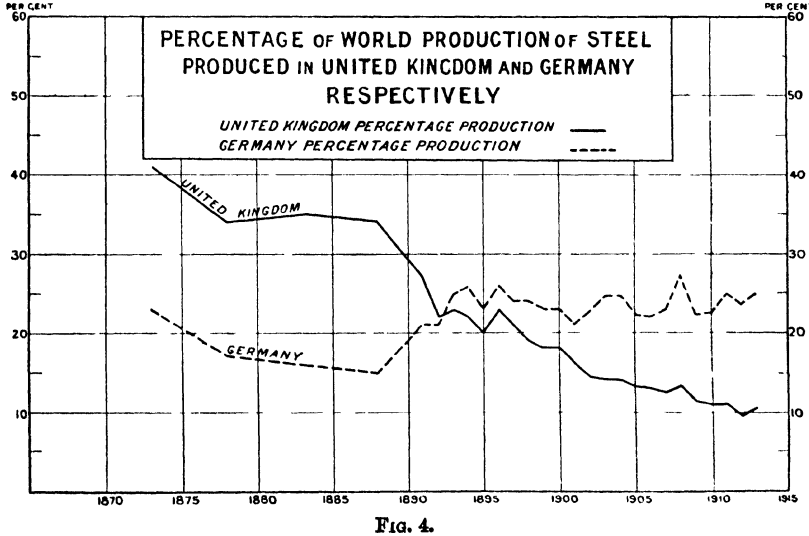

PERCENTAGE OF WORLD PRODUCTION OF STEEL PRODUCED IN UNITED KINGDOM AND GERMANY RESPECTIVELY
UNITED KINGDOM PERCENTAGE PRODUCTION
GERMANY PERCENTAGE PRODUCTION
PER CENT
UNITED KINGDOM
GERMANY
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915

FIG. 4.

by our jealousy of this progress of Germany. Perhaps you will consider it waste of time to even allude to this matter; but I will take this opportunity of pointing out that if there had been any truth concerning this jealousy, it would have been the simplest thing in the world to shut Germany out of a large number of markets in the British Empire, and that this would have been a very much cheaper process than going to war. Our Colonies, which are now fighting equally with ourselves against German aggression, made a very small difference (5 per cent., for instance, in the case of New South Wales) in regard to the introduction of German manufactures. I myself have somewhat close knowledge of two colonies, and I cannot help recalling the astonishment with which I found in South Africa that, when there was a huge scheme of electrification effected, the enormous amount of material which Germany supplied was for what the public mostly believed to be a purely British enterprise. I also have reason to know that the supply of machinery to New South Wales from Krupp in some cases exceeded by as much as ten times in amount the quantity supplied by British firms. The prices were no higher, in spite of the 5 per cent. advantage to this country. The delivery of the goods was on the one hand sometimes inordinately delayed, though scrupulously punctual in delivery on the other.

Now, when we look closely into the causes of Germany's great advance, we can learn lessons which we have been culpably slow to take to heart. Although there are other causes, first and foremost, and overshadowing all others, the determined and whole-hearted organisation of German industry. I see it recently stated that the scheme above referred to (the Victoria Falls scheme) was lost to this country because the industrial banks of Germany backed their own manufacturers, and this is no doubt partly true. As I have already quoted, Germany's power in war is admitted to be her mechanical organisation, and the organisation of every material and engineering force to that end. Just as striking, if not more so, is her organisation for the arts of peace, and I lately heard a very shrewd man of affairs express his amazement at Germany's entrance into war, when by peacefully pursuing the way she was going she would have dominated the world commercially in a few years' time, and, in the words of the speaker, might in many manufactures have made us practically bankrupt. It is undoubtedly in the matter of scientific organisation even more than the organisation of science that Germany has achieved such wonderful results, and it is therefore in this direction that we must leave no stone unturned if we wish to have any chance of holding our own in the future. I will indicate a few of the matters in which there is ample scope for doing useful work in the above direction.

Education.

A sign of the times is the inclusion of an Education Section in an association for the advancement of science. This has not been done on the narrow ground of improving the teaching of science in schools, but because it is now recognised, and this none too soon, that the whole problem of education must be treated in a scientific manner.

When the subject of engineering education is mentioned we are apt to think only of the training of such engineers as have been considered in a recent report issued by the Institution of Civil Engineers, and to exclude, as that report purposely does, the training of our artisans and foremen. We certainly do not connect the idea at all with the training of the artisan himself. As a matter of fact, while high scientific training of the professional engineer and manufacturer is of vital importance, the proper education of the men whom he will have to control is scarcely less so. The latter education may not be of the same kind, but it is just as vital to the country, and its present condition is a serious evil.

A well-known American, in the 'General Electric Review,' writing on the 'individual and corporate development of industry,' points out that theoretically the aim of both employer and employee is the same, namely, the efficiency of industrial production to increase the return of the investment in labour and in capital. Unfortunately, however, as he remarks, 'the relations between the two have frequently been hostile industrial warfare over the distributions

of the returns rather than co-operation for the increase of financial returns of both parties.'

One of the most humiliating things of the present War has been the mutual relation of the two in this country in what is probably the most critical period in our history. I will say more later on this subject, but there is no doubt the subject of industrial education needs earnest consideration. Take the first, the education of the professional man—the class, for instance, joining such institutions as the Civil, Electrical, or Mechanical Engineers; we find in one respect a most satisfactory progress as to what is insisted upon before such men are allowed to join one of these bodies. All such institutions now demand technical diplomas or University degrees, and, in addition, satisfactory evidence of practical training. But to prevent injustice to the man who may be self-taught, they hold examinations conducted by recognised men of standing in scientific and technical subjects. Great as this progress has been in recent years, there is a great deal to be done. In the first place, professors and teachers of engineering and technical subjects have to deplore the miserable previous training of a large number of students. It seems still to be a common idea that if a boy is unable to make any decent progress in the usual school subjects he can be sent to a technical school if he is useful with his hands, under the pathetic impression that the success of the engineer depends upon his hands rather than upon his head; and the first year or two at a technical school or college is thus taken up with work that ought to be done at a secondary school. It is not fair to put all the blame upon the school, for I have known students coming from the classical side of such a school with no knowledge of science and very little of mathematics who have taken the highest places in the engineering course, and, after entering their practical work, rapidly risen in the profession, and this was because such men had been well trained to apply their mind to any subject and had a sound foundation upon which to build. This only shows that a good student will always rise to the top, and does not prove that the present school system is the best for an average boy or makes him work as hard as, for instance, the corresponding school in Germany does. A large number of thinking men are convinced that our whole education system seriously needs reform. I say this not merely in reference to scientific education and technical training, but to the whole attitude of mind of the young of all classes of the community towards the serious work of life when they leave school. I will allude to this under another heading later on. In the matter of education and its bearing upon technical training, we have, then, a good deal to learn from Germany. There are some things that we think are quite as good if not better in this country, but there is no reason why we should not try to find a way to adopt the better features of education from our enemy, and, while retaining independence of thought and originality, inculcate firmer discipline, for there is surely a happier medium in this matter.

There is one matter before passing from this subject which calls for remark. I see in the report above alluded to there is a great divergence of opinion concerning the wage-earning value of highly technical students. Here again is a matter which in itself is worth a very careful discussion. The question depends first upon the student himself, next upon the kind of training he has had, and then upon the nature of the work he is expected to do. The blame in not getting the best results from a well-trained student is very often due to the employer, and our Section might do something to bring professors and employers into closer touch, and both employer and professor may have something to learn from each other.

In leaving this subject I cannot help pointing out what important continuation schools are to be found in the meetings and discussions of the younger members of various engineering societies, and how much a young engineer learns in the preparation of a paper. Anyone who is accustomed to take the chair at such meetings will bear witness to the excellent outlay of money represented by the award of prizes and medals for such work. Many men to my knowledge have got jobs through thus showing acquaintance with a special subject or originality of thought.

Research.

If there is one thing more than another which the British Association can be congratulated upon, it is the work which it has done in the matter of research, and it is very interesting to go back to the earliest days, more than eighty years ago, and to see how, in very different days from the present, research in all branches of science was encouraged, and what a potent factor the various meetings have been, not only in actually fostering the work of research itself, but in obtaining the recognition which is accorded to-day. Amongst other things, the National Physical Laboratory stands largely to its credit, as having been first powerfully advocated at one of its meetings. This Section has not been behind the others, and at the present moment there are three Research Committees, viz., those on Gaseous Explosions, Compound Stress, and Impact. The work of the first of these is so valuable that its results have been published all over the world.

To-day there is a more general recognition of the importance of research, and the recent institution by the Government of a Committee for the organisation and development of scientific and industrial research is the latest indication that the nation is beginning to realise its importance.

So far from all this making our work less necessary, there is all the more reason why we should have a permanent Committee of Research, because one of the intentions of the new Government Committee is to utilise the most effective institutions and investigators available, and the statement is made that one of the objects of the Government Research Committee is to select and co-ordinate rather than originate, and that one of its chief functions will be the prevention of overlapping between institutions and individuals engaged in research. The Government Committee in question is only dealing with the organisation in England, Wales, Scotland, and Ireland. Now, the great advantage possessed by this Association is the fact that it includes not only Great Britain and Ireland, but all the Colonies, and indeed one of the three researches above mentioned is being carried out in Australia. Another research of the Association is being carried out in Cyprus; and work is also being done in such places as Jamaica and Egypt. It is more important therefore than ever that the British Association work in research should go on, as, since its members are drawn from all parts of the British Empire, its influence should be correspondingly great.

There is another reason for research being a subject of a permanent sub-committee, and that is that suggestions for new work are more likely to be matured, and work of an advisory nature made more practical than is possible at one annual meeting.

There is yet one more reason, which is that, although we have made some progress, we are still far behind Germany in the organisation of research. There is no doubt that our students and scientific men are quite capable of conducting researches, but the training for this is like the training for the officers of an army: it cannot be done hastily; and, indeed, men themselves cannot be obtained for this purpose without years of preparation All such work must be done as a factor in the reorganisation of our manufacturing and commercial resources in the great struggle that lies before us.

There is one subject which affects both education and research, and might be a matter to be reported on by our Committee It is very rarely that a professor is both a good teacher and gifted with the power of original research. Even when a professor or lecturer is so gifted, however, it is almost impossible for a man to really devote himself properly to research, and at the same time undertake the duties which are attached to a professorial chair. Why not face this subject boldly, even relieve the bad lecturer (there *are* men who admit their failure in this respect) of a certain amount of his work, provided he is doing well in research; or for the man who can do both well, see that he not only has efficient assistance, but even more, that he is given the opportunity of devoting long periods (for instance, alternate years) entirely to research.

There are numerous other questions which would come up under this heading, and which could be usefully dealt with by our Committee.

There is one more subject that we might consider, and that is a better differentiation of researches on purely industrial work, such as are often of a most

profitable nature to the professor or research student, and those which are of a purely scientific character. While it is only right that every successful research, even if conducted at the expense of a public body, should bring solid return as well as fame to the worker, some steps should be taken as to the fair and equitable distribution of the proceeds. I see that one of the proposals of the new Research Committee is that discoveries by institutions, associations, bodies *or* individuals in the course of researches aided by public money shall be 'made available under proper conditions for the public advantage.' If the discovery is patentable, I assume, it would be protected at home and abroad, unless we wish to spend public funds as much for the benefit of foreign trade rivals as for ourselves. This is one of the many matters in connection with which a British Association Committee might from its cosmopolitan character render great service.

Standardisation and the Metric and Decimal System.

One of the favourite jibes at this country is our supposed utter want of system in regard to our standards and systems of measurement generally. With regard, for instance, to the decimal system, it is frequently stated that thirty or forty countries have adopted the metric system, while only three retain the inch as a standard. It must be remembered, however, that the population and wealth of the three latter are at least equal to, if not greater than, all the others, though this does really not prove anything, except the difficulty of the subject, and that there is a great deal to be said for both sides. In the Report of the Decimal Association last April, the hope is expressed that one of the changes for the better arising from the War will be a reform of our weights and measures. No class of the community would be affected more closely than the engineer, and engineers cannot fail to be interested in the question as to whether the general and immediate adoption of the metric system would or would not be a valuable means of assisting British firms in their competition with Germany and Austria, in countries where that system is in vogue. Although it is very unlikely that a wholesale change is imminent, it is certain that the metric system is gradually spreading, and in the United States and Australia very strong forces are on foot to bring about a change to that system. The British Association has over and over again had the subject before it, and our Committee might be of service in making a report on the present state of the matter.

One thing is certain: the Committee might be of assistance in recommendations which would bring into line all British engineers in duplicating tenders for countries which have the metric system.

Coming to standardisation, here we have more ground for satisfaction. The Standards Engineering Committee during the last ten years has done a work which is quite equal to that in any other country, of completing standardisation of all important matters in engineering, and, moreover, has secured the recognition of these standards in all public contracts. As giving some indication of the range of this work it may be said that there are more than sixty committees for dealing with every conceivable engineering matter, from bridges, ships, and locomotives down to electric lamps. One of the last of these committees, dealing with the automobiles, has eleven sub-committees, many of which have already completed their work. It is almost impossible to do justice to the extraordinary achievement of bringing order out of what was apparently hopeless chaos and to the benefit of the British engineering industry of this work, largely due to the energetic secretary, Mr. Leslie Robertson. We may justly pride ourselves that this Section was a pioneer of standardisation by taking up the subject of small screws, its work being taken over ultimately by the Standardisation Committee.

There is yet work to be done, however, and one matter of great importance would be to get a universal standard of temperature for instruments of measurement other than zero. A temperature, for instance, of about 62° Fahr. would make steel rods' measures more practically workable than at present.

In connection with the subject of temperature and standardisation, I recently came across a statement by the General Secretary of the International Electrotechnical Commission ('Journal,' January 1915) that the want of uniformity in the rating and testing of electrical machinery has been a serious

evil, and he goes on to say: 'The German standardisation rules, for instance, which, through well-organised and combined effort on the part of the German makers, had previous to the War become widely recognised on the Continent of Europe as well as in many countries to which British machinery is exported, by permitting a higher temperature rise than is considered good technical practice in Great Britain, certainly have not assisted the British maker in foreign markets.'

Exhibitions and Museums.

In recent years a large number of commercial exhibitions have been held of all branches of machinery, and it is satisfactory to note that one of the features of such exhibitions has been the holding of scientific lectures, and the inclusion of the exhibition of scientific instruments and apparatus, and also exhibits showing the relation of scientific experiments to engineering work. In some of the privately organised exhibitions with which I have been associated myself, the scientific men have been invited to take part when the general lines had been settled on which the exhibition was to be run, and thus we had comparatively little influence. I have thought from time to time that it would be well if a permanent committee of such a body as the British Association existed, which could exert more direct influence, chiefly of course by reports and recommendations. The managers and organisers of such exhibitions would value assistance of this kind, and in return would listen to suggestions which might materially add to the scientific value of such an exhibition. I know from experience that a British exhibition is a most important means of promoting British industry, for the number of inquiries that come from all parts of the country and from all parts of the world show how much interest well-organised exhibits arouse and what long distances people will travel to attend such an exhibition. A machinery exhibition was to have been held in London, the date of the opening a week or two after the date at which the War began, but was of course not held. This exhibition was to have been Anglo-Dutch, and though organised by private enterprise was even in advance bringing in touch the consumers and manufacturers of the two countries. The *Beama Journal* quoted recently an American magazine in which the writer was advocating the support of a permanent Commercial Museum for industrial purposes, and this is what he said: 'We produce a surplus of manufactures that must be sold. Our manufactured exports have about doubled in ten years—in truth a cause for satisfaction, and yet we have not accomplished enough. . . . We have only made a beginning, considering what we can do and will be forced to do in the future. . . . Manufacturers must compete with old-established nations in the market they seek to invade.' It is noteworthy that this museum, which is really a permanent exhibition, is a very complete organisation, containing amongst other things science laboratories.

It is sad to think that the great hopes held out of the Imperial Institute by the President of this Association, Sir Frederick Abel, at the meeting held in Leeds in 1890, have not been altogether fulfilled. The President expressed the belief that amongst other objects the Institute would combine 'the continuous elaboration of systematic measures tending to stimulate progress in trades and handicrafts, and to foster the spirit of emulation amongst the artisan and industrial classes.' It may be a very fitting time to bring forward the whole question, because it has often happened that an excellent scheme which has somewhat languished has upon its revival at a later time, when its importance was better realised, been crowned with success.

Another matter which might be considered is the question of departmental museums at the Technical Schools and Universities throughout the country. The organisation of these is simply a matter for the enterprise of the individual professor in each department. The museums in the Engineering Department of the colleges with which I have been associated were very much appreciated by the students, who constantly were the means of securing fresh specimens, and after they have left the college continued to contribute articles of great interest, such as fractures, corrosions, boiler plates, models, &c. This matter might be handled in a much more systematic manner, and possibly a report from our Committee with a recommendation to the proper quarters would be of use.

Patents and Patent Laws.

This subject is well worthy of the consideration of the proposed committee since progress in Engineering, certainly on the mechanical and electrical sides, is largely dependent upon invention, which is not likely to be seriously undertaken without adequate protection, not entirely for the inventor, but also for those who really make the invention practical by means of capital and business support. A great deal of nonsense is talked and written about inventors, as if they were a special class of being, generally mad and always impossible. Some inventors are both, but the fact is, most engineers spend their lives seeking new ideas and devising new methods of carrying them out—in short, in inventing. It is of the greatest importance that every step should be taken to encourage sound invention and to see that anything of value is secured for this country. Of course, every invention worth anything is immediately known in other countries, but I need not argue to this Section that the country which actually produces the inventions is at a great advantage quite apart from the royalties payable on foreign patents. The foundation of the Munitions Invention Panel is a step in the right direction, and will doubtless be followed later on by Government Committees for peace inventions. Such Committees or Government Departments dealing with various industries will be assisted by suggestions from a body like this. Take, for instance, the present state of Colonial patents: within the last few years one Commonwealth patent has been made to cover the whole of Australia, instead of there being, as of old, separate patents with different regulations and fees for each separate Colony. South Africa has not yet conferred a similar boon upon inventors, and we might do something to expedite this desirable innovation. But this touches the much wider question of Colonial Patent Laws as a whole. These are all different and differ from those of the Mother Country. It would be a splendid thing if we could bring about a conference leading to unification of these diverse Patent Laws and have one comprehensive Patent Law for the whole Empire.

There are many other matters—for instance, the question of extending the time of secrecy in the provisional patent. The 'close' time in patents was the act of Chamberlain, and is a splendid legacy of that great man, but for really many important patents the close time allowed is not enough.

Another is one in which the German system has certain advantages, viz., in having two classes of patents. One of these is the patent 'proper,' which is only granted after the most severe search and criticism, and holds the usual period when granted. The other is a secondary patent granted for the shorter term of five years, and is given for one of the hundred and one minor improvements and devices which, though of real value, only constitute small modifications in detail and not new applications of principle.

Having previously spoken of German ways pretty plainly I should like to say here that I believe the suspicion of injustice to the British and other foreign applicants by the German Patent Office is to a great extent if not altogether unfounded. It is doubtless true that German manufacturers in common with most of us would like to avoid paying royalties, and it is moreover a common belief in this country that there is an advisory committee of manufacturers associated with the German Patent Office. This view is supported by such statements as in the prospectus of the Deutsche Maschinenfabrik, which runs as follows: 'With the present-day competition every firm is compelled to protect its new designs by means of patents, *and watch that no other patents are granted* which would seriously effect (*sic*, affect) it.' Notwithstanding an utterance like this, my own experience and that of others is, that if the stringent rules of the German system are observed any valid application is granted, the motto which appears to guide the officials being, 'We will be just, but we cannot afford to be generous.'

There are other matters, such as the question of giving wider powers to our Comptroller to refuse a grant where novelty is less than microscopic. Here again the German system of demanding that some definite principle is applied *to produce some definitely new effect*, might to some extent be followed, especially in view of the constant accumulation of published devices, some patented and others not.

I will conclude this section, which is far from exhaustive, by pointing out what a debt of gratitude Engineers and others owe to the Patent Office for the manner in which the work of producing illustrated abstracts of all patents has been and is being done, and the weekly issue of the 'Patent Journal,' but this may be associated with the suggestion that it would be a real convenience if, instead of the delay which often occurs, the abstract appeared at the same time or immediately after the publication of the complete specification.

Organisation.

This, I venture to think, is by far the most important question of any I have raised, and I will go so far as to say that I believe it to be the all-important one, as it practically embraces the others. If you do not agree with me, I feel sure it is because we do not understand the same thing by the word 'organisation.' When you speak of organisation to most people they immediately seize upon some small feature which may be to them of more immediate interest. It may be the general arrangement of their accounts, their system of store keeping, of dealing with their workmen, of the sales department, or fifty other minor details. If you take this narrow view of organisation you will, of course, at once say that a scientific man has very little to do with it, and indeed the manufacturer as a rule, thinking of his works organisation, scouts the idea that a man of science can either know or have anything to say about it which is of any value.

Let me therefore take the dictionary definition. To organise is to 'arrange or constitute interdependent parts, each having a special function, act, office, or relation with respect to the whole.' If we accept this definition, which as a matter of fact we must, there is no question as to the all important nature of organisation, for you will notice there are two outstanding things. The first 'interdependent parts' and the second their 'relation to the whole' Thus the subject of organisation really includes the whole of industry. It includes science and its relation to manufacture It includes the relations between the employer and employee. It includes the workman, and his attitude towards new devices, labour-saving appliances, and output. It includes the whole question of the supply of raw materials, and even the sale and delivery of the finished article. Taking these different features, is there any doubt that the man of science in this country can hold his own, and more than hold his own, with that of any other? The history of invention is quite enough to give a final answer to this question. Again, the British employer and man of affairs has always shown himself individually in the forefront of enterprise; as for the workman himself, he is admitted, in the matter of intelligence, physical endurance, and skill, to have no superior; while with regard to materials for manufacture, and the power of delivering goods, it need scarcely be said that the British Empire, if we take it as a whole, is the richest country in the world in raw materials, and its means of delivery of its goods is expressed by the enormous preponderance of its mercantile marine

When we come, however, to these interdependent parts and their relation to the whole, it is there that we find the weak joint in the armour. It is in this respect that Germany can teach us a striking lesson in the *arrangement* of these interdependent parts with respect to the whole. From the top to the bottom the whole forces of their industries are so thoroughly organised that they get all that is humanly possible out of the various factors. I do not limit this merely to the wonderful organisation of any works, like Krupps, or the Deutsche Maschinenfabrik, or hundreds of other works, but I include the organisation of all the Government Departments, together with the Banks, the Railways, and the Shipping, so that every facility is afforded for the world commerce of the German Empire.

Taking only one of these details, I remember, when at Liverpool, and the battle of the Manchester Ship Canal was being fought, what facts came out as to the difficulties in the transhipment and handling of goods. The late Mr. Alfred Holt, for instance, was one of the most earnest in pointing out that the want of co-operation and organisation in getting goods from our manufacturing centres was adding largely to their cost, and actually exceeded the cost of

transporting these goods across the ocean. In Germany, on the other hand, the Government steps in, and by means of special differential rates, gives the manufacturer every facility, and the lowest possible rates for obtaining raw material, and delivering the finished goods to all parts of the world. It was this organisation that not only rendered Germany so formidable a rival in times of peace, but makes her so powerful in war.

This co-ordination in Germany is carried out in every industry in a way we generally have little idea of. For instance, the other day at a deputation to the Government Mr. Runciman remarked that the difficulty of connecting the manufacturers with the commercial staffs in this country is deep seated, but perhaps not altogether incurable. Further, that the manufacturer must realise what he can get from the universities, and the University must know what the works require. Dr. Foster, the Treasurer of the Chemical Society, also said that 'the Germans were so imbued with the need of pursuing modern and efficient methods of education, in applying science to industry, that they hold in contempt a country which notoriously neglects such processes'; and he attributed this contempt as partly contributory to their cheerfulness in entering into the war with us.

Now, while these remarks are undoubtedly true, they are only a part of the truth. The evil is far wider than in any special application, for, as the German knows perfectly well, there are innumerable individual cases of organisation in this country of equal efficiency to any in his country, and he is glad enough to learn from special cases. Let us take one, and I do so because it shows that the man of science is capable of industrial and manufacturing organisation, if he turns his mind to it. I refer to the case of the firm known as Barr and Stroud, Ltd. As you know, the founders of this firm were originally colleagues in the Yorkshire College (the former, Professor Barr, occupied the Presidential chair of this Section three years ago), and they together invented a range-finder. Now, whatever the merit of this range-finder, it is safe to say, like every other important invention—for instance, the Parsons turbine—that the invention alone would have stood a small chance of coming into practice. In fact, to make the invention is, as a rule, the beginning of the difficulty. Professors Barr and Stroud, however, set to work to carry their invention into practice, and did so with such effect that their works, which began on quite a small scale, rapidly grew, and the first part of the new works was opened with about 90 hands all told in 1904. In the course of ten years it has increased to such an extent that there are now 1,700 employees. Those of us who have visited the works at Glasgow know the almost perfect way in which the whole arrangements are made, not merely for the scientific side, but for the comforts of the men, including the working dress which in itself becomes a uniform. It gives some idea of the scientific side to know that there are at the present moment twenty-three men with high university qualifications, most of them with university degrees, and many of them men who were absolutely the first on the college list in the final examinations. This industry is another illustration of the lead given to Germany by this country, because the Barr and Stroud range-finders were brought out before any of the German range-finders of the kind now being made, the Germans having followed in their lines, and copied them in many respects. I have enlarged upon this, because I cannot help pointing out that the Barr and Stroud range-finders have had no small effect in the marvellous precision of our naval guns, and it will no doubt pass through your minds what we owe to private enterprise which started the manufactures of the turbines, range-finders, guns, and other naval features, when we think of such battles as those off Heligoland or the Falkland Islands.

Now I do not believe the Germans despise us for our want *per se* of the application of science to industry. I do not think they have much reason to; but what they do despise us for is the want of co-ordination, which I venture to say amounts to positive slackness, which they are keen enough to observe permeating the whole of this country. They see different sections, instead of being united for a common end, quarrelling with each other, filled with mutual suspicion and distrust, with apparently no common bond of union; and whereas the German is proud of the Fatherland, he sees in this country large numbers

who seem, either through self-consciousness or ignorance, to be ashamed to mention the subject of the British Empire, or, what is worse, to acknowledge that any love of their country is or could be a mainspring and incentive to strenuous effort.

The other day, Field-Marshal von Moltke stated—and there is no reason to disbelieve him—that great as was the storage of ammunition and shells before the war, the enormous demand far exceeded all expectation, and Germany found herself for a time in the same plight as her enemies, but he further stated that Germany's emergence 'from this dangerous position was largely due to the extraordinary organisation, which included not merely the adaptation of their factories for munition purposes, but *capacity for work of the people*, and the *patriotic spirit of the German workmen.*'

This brings me to consider what is probably the most serious feature in our national life to-day, which I have already alluded to under the heading of Education, viz., the relation of employer and workman. It is hopeless, as long as such ideas prevail which seem to do at present, to think of any sound organisation of our industrial system taking place, because the interdependent parts are not arranged (and can never be arranged until we change radically) with respect to the whole. Now as one who has served an apprenticeship, who has taken his money weekly from a tin box with hundreds of other men, who has been a member of the Amalgamated Society of Engineers (in fact was working as an engine fitter when a Whitworth scholarship made a college career possible), I am the last man to put this evil down entirely to the working man. I know individually he is just as capable of patriotism as any other class. Get him by himself, even the men whose strikes have caused such despondency in the minds of our Allies, and who have seriously jeopardised the very existence of the country, and you will find (except in the sort of case to be found in all classes of society) that he, as an individual, is willing to make sacrifices, and if necessary to give himself for his country. The truth is that the canker which is eating the heart out of our industrial life is due to an entirely wrong attitude of mind. For instance, however much we may sympathise with men who see a loss of employment in the introduction of labour saving machines, some means should be found by which they can share the benefits to the State and to their employers by the introduction of such machines. I should like, if I had time, to say something about the marvellous organisation of the Ford motor-car works in America, and how it has given the men a share in the returns of a great industry, and thereby induced them to work in a way that has enriched themselves, their employers, and their country. We have many splendid examples of this co-operation in this country. For instance, Messrs. Allen, of Bedford. Again, the employment of women in the engineering industries has taken place in many directions owing to the War. The works with which I am associated could not have undertaken much munition work without it. Some steps should be devised by which this avenue of industry is not closed to women after the War, while justice is secured for the men alongside of whom they are working, and from whom they are in many instances learning mechanical skill. Again, the questions of piecework and overtime must be seriously considered by the State, and not allowed to become the subject of disastrous disputes. Once more there is the question of a standard wage. It is against the eternal laws of nature to try and keep living beings at one dead level of equality and merit—*i.e.*, it is against the law of the survival of the fittest. The trade unions have a great opportunity of placing their country and themselves in a leading position amongst nations if they will courageously grapple with a great problem by recognising degrees of merit and corresponding degrees of payment These are a few of the many matters which must be dealt with in the immediate future.

The matter of labour disputes is so serious as to demand plain speaking. It must be admitted that there are many employers and companies which, to satisfy themselves and their shareholders, extort the largest possible dividends and pay the smallest possible rate of wages, and do so apparently without the slightest idea that the men and boys under them are capable of education and personal influence. Can it be wondered at then that men under these conditions

are willing enough to listen to the orator who merely appeals to their fighting instincts and join in the game of grab as against the employer? On the other hand, strikes have occurred when employers have honourably carried out their obligations and undertakings, and the men have shamefully departed from an agreement made by their chosen leaders, throwing over the leaders the moment they have fancied it to their own selfish interests to do so and without a single thought of their duty to the community as a whole.

We have recently seen the Prime Minister and other leading statesmen struggling, sometimes in vain, to bring large bodies of men to a reasonable state of mind. Is not this (and I speak without the slightest reference to party questions) a case of Nemesis overtaking us for having in so many cases pandered to the selfish instincts of large bodies of men in order to secure their votes, instead of sternly telling them unpalatable truths?

There was recently an intensely interesting article by the late Professor Friedrich Paulson, previously Professor of Philosophy in Berlin University, published in the 'Educational Review' of New York. In this article, the subject of which was 'old and new fashioned notions about education,' he pointed out that the whole of our educational system was going wrong, and that we could not escape the conviction that a tendency towards weakness and effeminacy was its chief trait. His three mottoes were: learn to obey; learn to apply yourself; learn to repress and overcome desires; and he remarked with great truth under the first heading: 'He who has not learned to do this in childhood will have great difficulty in learning it in later life; he will rarely get beyond the deplorable and unhappy state that vacillates between outward submission and uproarious rebellion.'

Is not one of the first things the reform of our educational system?

The other day a writer in the *Spectator* said with great truth that 'what Great Britain is suffering from acutely and dangerously at the present time is the absence of discipline,' and a neutral writer in the *Times* remarked as follows: 'The uniformity of German effort, due doubtless to their myriad well-organised, machine-like minds, though it renders them excessively tiresome people to dwell among in peace time, enables their Government to extract every ounce of energy in the conduct of a war.' He further went on to say that the British Empire 'could not have been created by minds like these, but it should not be forgotten that in the concentration necessary to national effort in a struggle like this the German system of self-subservience to the State has enormous advantages.'

One of the tasks to which the British Association might bend its energies with the greatest benefit to the country, is to bring about a reform of our educational system, so that while we do not kill individual enterprise and freedom of thought, which have contributed so largely to the political organisation and constitution of the British Empire, of the value of which we have had such wonderful evidence from our Colonies and dependencies during this War, we seek to implant in the minds of young and old those ideas of discipline and service to the State, the want of which so seriously threatens the successful organisation of our industrial life.

Conclusion.

In bringing my address to a close I hope I have made it clear that I have had throughout a practical object. Expressed briefly, it is that the service of every agency is wanted for definite work at this crisis, both in the actual war, and afterwards in the war of industry which will be waged with equal intensity in peace time. The British Association cannot be said to have undertaken as a whole a work of this kind, yet one finds a general desire on the part of every member that something should be done. With this object I communicated with the President, and found that both he and such of the officers as could be got in touch with were in entire sympathy with the general proposal, and advised that our Section, like that of Economics, should start at once with a committee on the subject. I have great hopes that such a committee will be formed, but I have no hopes of either our own sub-committee or the committee of the Association as a whole doing any good, unless they are

prepared with definite suggestions and advice which cannot be ignored and put aside. I have not the slightest faith in the mere formation of a committee which will content itself, let us say, with the mere offer of its services, even to a Government department, and the mere pious expression of certain opinions. If a committee does not want to become ridiculous, it must show that it is in earnest. To show that it is in earnest it must take care that its reports have a practical object, can be at once grasped by overworked Ministers and officials, and are of real value. Of course there are incompetent people in public departments, possibly even in the Admiralty and War Office, and many good proposals and suggestions are turned down—or, let us rather say, have been turned down in the past—because they happened to pass into the hands of such people in the first place, and there was not enough driving force behind them to follow the matter up.

When I first used to attend meetings of the British Association there was a gallant officer (Captain Bedford Pim) who had commanded various men-of-war, and was patriotically concerned with the state of the British Navy. I remember well his formula, which I heard on many occasions, as follows: 'The British Navy, sir, rotten—rotten from stem to stern, from truck to keel.' Such a sweeping statement about a service of which we are all proud only served to raise a prejudice against him, in which I shared myself, and excited the suspicion of undue bias or twist of mind. As a matter of fact, as it turned out afterwards, and has since been admitted over and over again, he was essentially right, and now that we realise our obligations to the British Navy, and that it has really saved this country, one trembles to think what would have happened if it had then been called upon in the same way as in these days. The above officer was afterwards made an admiral, though I am afraid it was not as a reward for his candour, or even to head off his criticism, because nobody seemed to take much notice of his warning. The moral that I have in mind is that if our committee is going to be of the slightest service, while formulating its proposals in temperate language, it must unflinchingly follow them up, and not allow them to die unless they are proved to be worthless, but to see they are seriously taken up and carried into operation.

Fortunately the British Association is a powerful body with great traditions, and will be listened to if such work is carefully and energetically done. Think, for instance, there are many eminent men who have supported this particular Section in times past, and many of them in the chair, such as Robert Stephenson, Scott Russell, Lardner, Moseley, Willis, Whewell, Whitworth, Vignoles, Fairbairn, Rankine, Hodgkinson, Sopwith, Babbage, Hawksley, Hawkshaw, Barlow, Armstrong, Froude, Bramwell, Baker, Douglas, Osborne Reynolds, White, and many others. Think of the mark that these men, now passed away, have left on the history of the British Empire, and let us see to it that this Section does something worthy of its past history. We can at least congratulate ourselves that whatever the evils of the War, the country as a whole has been moved from its usual attitude of self-complacency, and that the numerous new departments and organisations are showing a desire to utilise every force and agency for the service of the State, and to grapple with the great problem of its more efficient organisation. It will be no small work of a British Association committee if it can supply sound ideas and recommendations on the many thorny problems which must be solved. We cannot all of us be, as so many would like, in the fighting line, either in France or the Dardanelles, but we shall be just as deserving of contempt as those who, having had the opportunity of service, have shirked their responsibilities, or the giving up of their sons, and are even thinking of the War as a matter of personal gain, either in purse or reputation, if we content ourselves with mere offers of service, and having as we think shelved responsibility by leaving initiative to others, we pass along our way sheltering ignobly behind those men and women who are doing their duty to their country.

The following Report and Papers were then read :—

1. *Experimental Investigation of the Thermal Efficiency of a Gas Engine* By Professors G. ASAKAWA *and* J. E. PETAVEL.[1]

At the Birmingham Meeting of the British Association a preliminary note bearing on the above subject was read. The investigation has been continued during the last two years and has led to the conclusions summarised below.

The various losses have been separately determined by measurements based not on indicator card readings, but on the rate of change of the kinetic energy of the rotating parts, and thus the errors inherent to the indicator mechanism have been avoided.

In the following summary the performance of the engine is compared with that of a perfect engine working on the same cycle and with a similar gas mixture.

Indicated Horse Power.—At full load under the most favourable conditions the indicated horse-power of a gas-engine is 88 per cent. of that of an ideal-engine working with a similar mixture.

This holds true for all except very weak mixtures, for which the relative efficiency is lower.

For mixtures containing only a slight excess of air, the above corresponds to an absolute thermal efficiency of 27 per cent. at a compression ratio of 3·75 and 33 per cent. at a compression ratio of 5·6; for mixtures containing twice the amount of air required for complete combustion the absolute efficiencies are 29 per cent. and 36 per cent.

The indicated efficiency relative to the gas-standard falls from 88 per cent. to 84 per cent. between full and no load.

Brake Horse Power.—At the full load the brake efficiency relative to the gas-standard varies from 70 per cent. at the compression ratio 3·75, to 67·5 per cent. at the compression ratio 5·6; this holds true for all except the weakest mixtures, for which the relative efficiency is lower. The absolute brake efficiency is 21 per cent. at compression ratio 3·75 and 25·5 per cent. at compression ratio 5·6 for mixtures containing little excess of air, and 23 per cent. and 27 per cent. respectively for mixtures containing twice the amount of air required for complete combustion. The maximum brake efficiency obtained in the present experiments was 27·4 per cent., and occurred at the highest compression ratio for a mixture slightly stronger than this.

At light loads, the brake efficiency relative to the gas-standard decreases more rapidly as the compression ratio rises. For the higher compression ratios the increase of theoretical efficiency is just counterbalanced by the increase in frictional loss, and thus the absolute efficiency remains constant.

Mechanical Losses.—The mechanical losses increase slightly in absolute amount with the load and with the compression ratio. For the engine under test (a 25 H.P. National Gas Engine) at normal speed (200 revs. per min.) the mechanical losses amounted to 5·6 H.P. at no load and 6·3 H.P. at full load when the compression ratio is 3·75; and 6·5 H.P. at no load and 7·0 H.P. at full load when the compression ratio is 5·6.

The pumping losses are an important part of the total mechanical losses; at a compression ratio of 4·85 they represented 2·3 H.P. at no load and 2·1 H.P. at full load, or 38 and 31 per cent. of the mechanical losses.

Thermal Losses.—The loss of power due to thermal losses at full load under most favourable conditions amounts to 12 per cent. of the total available energy, and at no load to 16 per cent.; of this less than one quarter is due to heat transmission during the expansion.

2. *Report on Gaseous Explosions.*—See Reports, p. 158.

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[1] See *Engineering*, September 17, 1915, p. 297.

3. *The Total Radiation from a Gaseous Explosion.* *By* Professor W. M. THORNTON.[1]

4. *The Change of Specific Heat of Gases with Temperature.* *By* Professor W. M. THORNTON.[2]

5. *A Machine for determining Fatigue Limits Calorimetrically.* *By* C. E. STROMEYER.

The following is a brief description of a fatigue-testing machine constructed for the Manchester Steam Users' Association for the Prevention of Boiler Explosions.

A motor, by means of a chain drive, rotates a low-lying shaft to which three sprocket wheels are secured. These are connected by chain drives to three independent overhead spindles and steel discs, the spindles revolving in bearings which are free to move horizontally. Eccentric weights are attached to the discs and horizontal rods to the sliding bearing, which end in attachments for the test pieces, viz., the left-hand rod is attached to a lever which imparts alternate twisting movements to a torsion test piece, the centre rod is attached to a push and pull test piece, and the right-hand rod is attached to a yoke, connecting rods and levers, which produce alternating bending stresses in a bending test piece. The rotation of the eccentrically weighed discs causes the bearings and their rods to oscillate horizontally, whereby alternating stresses are produced in the test pieces. The central rod is provided with attachments which permit of applying steady pressures or pulls by means of flat springs. Push and pull tests can therefore be carried out between any desired limits of stress.

The eccentric masses on the discs of the two wing machines, for torsion and bending tests, are opposed to the mass on the discs of the centre machine, for push and pull tests the weight of the latter being equal to the sum of the former. By this means the revolving masses are balanced, and cause practically no vibration of the building, although the push and pull forces occasionally exceed two tons at 600 revolutions.

Both the torsion, push and pull, and the bending test pieces are practically stationary when being tested, and can therefore be surrounded with water-jackets, with the help of which the fatigue limits are determined calorimetrically. At first the flow of heat between the test pieces and the attachments interfered with the thermometer readings, but this disturbance has now been reduced, and will be still further reduced. It is also intended to use thermo couples instead of mercury thermometers. No systematic tests have yet been made, but one test confirms the result obtained by the British Association Committee, and reported upon at this Meeting, to the effect that there are apparently no separate fatigue limits for tension and for compression, but there are limits of range of fatigue stresses, which ranges are functions of the two applied stresses. The torsion and bending tests are in agreement with the push and pull tests.

The machine is now at work in the museum of the Manchester Steam Users' Association for the Prevention of Boiler Explosions, and can be seen by members between the hours of 10 A.M. and 5 P.M. In the museum, which contains a number of interesting examples of boiler mishaps, there are also on view several strain indicators, water hammer models, &c.

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[1] See *Phil. Mag.*, vol. xxx., p. 383.
[2] See *The Electrician*, vol. lxxv., p. 948.

THURSDAY, SEPTEMBER 9.

The following Papers were read :—

1. *The Manchester Drainage Scheme.* *By* DE COURCEY MEADE.

The drainage of the City of Manchester has occupied the attention of the City Council for many years, and the subject has been considered and reported upon by experts at various times during the past forty years. The natural drainage of the city is by the rivers Irwell, Mersey, Medlock, Irk, and their tributaries. The Irwell below Manchester is now absorbed into the Ship Canal. The area of the city has been largely extended since 1885. At that time it was only 4,298 acres; its present area is 21,688 acres—an increase of over 400 per cent. The writer's predecessor, Mr. John Allison, M.Inst.C.E., prepared plans for the drainage of Manchester in 1888. The area of the city at that time was 5,940 acres. The works designed by Mr. Allison were in progress when the writer entered upon his duties as City Surveyor 21 years ago, and those works were completed under his direction. Manchester has far outgrown the capacity of the drainage scheme devised by Mr. Allison, whose plan was calculated to be sufficient to serve a population of 868,522 persons, but before the sewage from 500,000 persons had been connected with the sewers they proved wholly insufficient, and outlets had therefore to be found for the surplus flood waters through the original channels which discharge into the rivers. That state of things has continued for many years.

Six years ago the writer was requested to prepare plans for the drainage of the present city, and also to provide for the requirements of any additional districts which it is probable may hereafter be added to the city. The latter part of the instruction introduced a somewhat difficult problem. After very careful consideration of the whole subject the writer submitted a proposal to the City Council, which was subsequently approved by Parliament, and the works designed by him are now partly completed. The absence of reliable data regarding the 'run off' of rainfall from urban areas by artificial channels is worthy of note. The want of this information led to an under-estimate of the sewer capacity necessary for the drainage of the Metropolis. The London basis was adopted by the writer's predecessor as sufficient for Manchester, and consequently resulted in a similar deficiency in the size of the conduits he provided for the drainage of this city. Most useful lessons were learned by these early projects, and information gathered by the writer during the past twenty years, by means of self-recording gauges and otherwise, enabled him to determine with reasonable accuracy the provision necessary for the reception and removal of the city sewage plus rainfall during periods of storm.

The intensity of rainfall, impermeability and character of surface, and the relative retardation of flow are factors which have an important bearing on the maximum quantity of flood-water which will pass into a system of town drainage. The duration of storm and the condition of the surface immediately preceding a fall largely affect the rate of flow. A rainfall of great intensity and a few minutes' duration may not produce an excessive flood, whilst serious consequences would probably result from a rainfall of similar intensity continuing for, say, a quarter of an hour, other conditions being equal. A chart showing the registered duration and intensity of storms in South Lancashire during the past fifteen years will be shown on the screen. The solid curve thereon indicates approximately the provision which experience has proved to be necessary in the new sewers and storm culverts for sewage plus storm-water; the dotted curve shows the maximum intensity of rainfall recorded during the period under observation. On the 10th ultimo a rainfall intensity of 3·75 inches per hour was recorded in the centre of this city. The storm affected, as is usual in such cases, a very limited area, which is not yet served by the new system of sewers. The surface of this catchment area was wholly impermeable.

The accompanying table shows the ratio of impervious surface to population :

STATEMENT SHOWING THE RATIO OF IMPERVIOUS SURFACE TO POPULATION.

Index Letter.	Locality.	Population per Acre.	Number of Houses per Acre.	Percentage of Area occupied by Buildings and Impermeable.	Percentage of Area occupied by Backyards, Gardens, and Open Spaces.			Percentage of Area occupied by Streets and Passages and Impermeable.	Total Percentage of Area Impermeable.	Total Percentage of Area Permeable.
					Impermeable.	Permeable.	Total.			
				Per cent	Per cent	Per cent	Per cent.	Per cent.	Per cent.	Per cent.
A	Hulme	179	38	42	15 67	·33	16	42	99·67	·33
B	Ancoats and Newton . .	164	35	36	22	2	24	40	98	2
C	Gorton	146	31	29	22	11	33	38	89	11
D	Harpurhey	136	29	26	32	11	43	31	89	11
E	Moss Side	103	22	33	32	8	30	37	92	8
J	Newton Heath	85	18	26	16	26	42	32	74	26
F	Withington	66	14	19	13	47	60	21	53	47
G	Chorlton-cum-Hardy . . .	52	11	18	19	40	59	23	60	40
K	Crumpsall	24	5	12	6	58	64	24	42	58
H	Rusholme (Victoria Park) . .	4·7	1	7	3	76	79	14	24	76

NOTE.—Each of the ten localities lettered A to K has an area of 50 acres The population has been ascertained by multiplying the average number of houses per acre by 4 7, obtained from the Returns compiled by the Registrar-General in the Census of 1911.

This table has been prepared from information derived from careful observation, and the actual run off has been determined by numerous gaugings within the defined areas. The table shows the relation between population and impermeable surface under the varying conditions which obtain in Manchester, and from it a useful diagram, which will be shown on the screen, has been constructed. This information was necessary in ascertaining the storm-water discharge and time of concentration, which is in direct proportion to the area of impervious surface; the gradients, of course, also affect the result.

The formula used in determining the flow of intended sewers has a very important bearing on the results obtained.

A diagram was displayed showing the discharge in cubic feet per minute in sewers, computed by various formulæ and by actual measurement into tanks of large capacity. The conditions in Manchester afford special facilities for actual measurement which do not obtain in other places. The diagram shows the curve derived from actual measurements and those constructed from calculation by formulæ in general use. It was found that the formula of Kutter coincides with the actual measurements when the value of n (the co-efficient of roughness) is taken as ·012 for good earthenware pipes and ·015 for brickwork of average construction and in good condition.

For the purpose of determining the correct sizes of the new culverts, and to prevent the possibility of their proving too small for the requirements of the future, the whole of the areas served by the existing sewers were segregated, and each area was then considered and dealt with separately. The dry-weather flows and the quantities of storm-water resulting from rainfall of varying intensity were measured, and the actual quantities correctly ascertained. These observations extended over a lengthy period. A large mass of valuable information was thus, by many years of careful and systematic record, obtained. If it had been available when the original sewers were designed they would doubtless have been constructed on larger lines; and, although the initial cost would have been proportionately more, the extra outlay would have been small compared with that now involved. The total capacity of the old and new outfalls below the point at which the excess storm-waters are eliminated exceeds 60,000 cubic feet per minute.

Under the statutory regulations of the Manchester Corporation, the dry-weather flow, which is based upon the water supply, has to be diluted by the addition of six times its volume of storm-water before overflow into the Ship Canal and rivers is permissible. On this basis the main drainage works referred to in this paper will be sufficient for a population of about two and a half millions.

When the British Association last visited this city (1887) the conservancy system was in use here; the dry system has subsequently been replaced by the water-carriage system. Since the writer entered upon his duties in Manchester no less than 82,874 cases have been dealt with, and in each case water-carriage was substituted for the dry system, leaving only 1,533 cases yet to be converted from the dry to the water-carriage system.

The author's new scheme of main drainage was commenced in April 1912, and about nineteen miles of large conduits have been completed since that date. They range in diameter from 15 feet 3 inches downwards. A view of the general arrangement of the main drainage of the city and the outside districts contributing to the scheme will be placed upon the screen. The whole of the drainage is conveyed by gravitation to the disposal works, which are situated about five miles outside the city on its westerly side. The total area at present contributing to the main drainage, including that arranged to be connected to the system, is 39,144 acres: the largest drainage area outside the Metropolis. When the new works are completed the outfalls from the city boundary to the disposal works will be in duplicate. This arrangement has many advantages over one outfall of larger size. In fact, it would not be practicable to construct one conduit to convey the quantity for which provision has to be made, especially in those lengths above the principal storm overflow, which is situated about half-way between the city and the disposal works. The approximate cost of the new work up to this date exceeds £600,000.

A portion of the work was carried out by the Corporation staff without the intervention of a contractor. The work so undertaken comprised conduits of

the largest size. The new work is composed of hard shale bricks set in Portland cement mortar. The internal linings of the smaller structures and the inverts of the larger ones are formed with red-pressed bricks, which make a smooth and durable surface. The large culverts cross railways, canals, and rivers. Owing to the presence of water it was found necessary in some sections to use compressed air; this method of construction was most successfully employed without the application of the working shield. In some instances lengths of upwards of three-quarters of a mile were constructed from one air-lock. Little trouble was experienced from air-leakage, although the depth beneath the surface did not exceed 30 feet, and in many places it was much less. The work is being carried out under the direction of the Rivers Committee of the City Council, and the writer desires to record his indebtedness to that Committee and to the Chairman (Alderman Frowde, J.P.) and the Deputy-Chairman (Councillor West) for the great assistance and encouragement he has from time to time received in dealing with the many difficulties that have arisen during its progress.

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2. *The Manchester Electrical Undertaking and the projected Barton Station.* *By* S. L. Pearce [1]

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3. *The Special Work in the Mechanical Engineering Department of the Manchester Municipal School of Technology.* *By* Professor A. B. Field.[2]

The following account is submitted mainly in view of the intended visit of the British Association to the Municipal School of Technology.

Much research work upon lathe cutting tools was carried out by the late Dr. J. T. Nicolson in the School of Technology, starting some ten years ago. The work has been continued at Manchester since then, and led to the development of a very complete dynamometer gear for measuring the various components of force upon the tip of the tool when taking a heavy cut. This apparatus, as constructed to Dr. Nicolson's design, can be inspected in the Engineering Laboratories at the School, and will be shown in action on an 18-in. heavy lathe.

An apparatus upon similar lines for measuring the various forces acting upon a milling cutter is also exhibited; this apparatus having been built to the design of Mr. Dempster Smith, who was associated with Dr. Nicolson in his work. Mr. Dempster Smith is continuing this line of research in co-operation with a Committee of the Manchester Association of Engineers.

In the materials testing laboratory, in addition to standard testing work, researches have been in progress by Mr. W. C. Popplewell upon the effects of repeated reversals of stress, using the rotating-beam method. The apparatus used is open to inspection. In the same laboratory will be found under way a research upon the failure of alloy-steel tubular struts of short length. Such struts fail by a process of crinkling, as distinguished from the collapsing of an ordinary long strut. The effects of various methods of end-constraint are being investigated in this connection, and corresponding tensile tests of samples of the material made.

In the gas engine laboratory experiments are being conducted by Professor Okamoto, of Osaka, to investigate the rate of loss of heat of the contents of a gas-engine cylinder, dividing this quantity into two items, which may be generally comprised under the headings 'conduction' and 'radiation.'

Other special work in the department is in hand for the War Office, and is not open to discussion now.

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[1] See *Engineering*, September 24, 1915, p. 309.
[2] See *The Engineer*, September 17, 1915.

4. *The Manchester Corporation Gas Undertaking.* *By* J. G. Newbigging, *M.Inst.C.E., Chief Engineer.*[1]

In this paper the author dealt briefly with the early history of the undertaking, and quoted figures from the accounts for the financial year ended March 1915, showing how it had grown since the year 1843, when the gas works became municipal property. The strong financial position of the undertaking was due to the Gas Committee continually availing themselves of up-to-date methods of manufacturing gas.

A brief reference was made to the important features of the works, more particularly recent improvements. In the first and most important process of gas making—carbonisation—the undertaking has occupied a foremost place in the gas industry. Manchester was one of the first to adopt mechanical stoking for charging and discharging retorts, and also constructed one of the earliest installations of inclined retorts, where the charging and discharging of the retorts is effected by the natural gravitation of the material. The undertaking has also been a pioneer in the latest and most scientific method of carbonising in vertical retorts. In this system the coal passes continuously through the retorts at a speed of from two to four tons per diem. The coke leaves the bottom of the retort in a comparatively cool state, the heat having been extracted by means of cold air circulating round the base of the retort. The advantages of this system as compared with the intermittent are : saving in labour, minimising loss of gas and other valuable products, and the obtaining of yields of gas of 13,000 to 14,000 cubic feet per ton, with a minimum percentage of inert gases in its composition.

At the Bradford Road Works a gas-holder of ten million cubic feet capacity has been constructed, and is one of the largest structures of its kind in the world.

Gas works have been brought into prominence through the War because coal-gas and its by-products contain substances which are either the basis of valuable explosives or are used in their manufacture. Manchester is doing its share in producing these important munitions of war.

The sulphur and ammonia produced in the process of purifying the gas are converted into sulphuric acid and sulphate of ammonia, the yearly production being 3,700 tons of pure acid and 5,000 tons of sulphate per annum.

The author pointed out that, great as the success of gas enterprise had been in Manchester, it would not be maintained unless the Department was allowed to sell gas at cost price, and relieved from the burden of contributing large sums annually in relief of rates. The author contended that the competition with electricity would not permit of this extra taxation of the gas consumers. He quoted statistics showing that in Manchester electricity and gas have their separate and distinct spheres of usefulness, electricity showing a steady increase for power and lighting, and gas for cooking and heating. In the case of a municipality controlling both the gas and electricity supplies he saw no reason why the former department should not eventually become the gaseous fuel supplier and the latter the light supplier. Gas of a calorific value of 250 to 300 B.Th.U. per cubic foot could be very cheaply produced, and this quality could also be used for lighting under high pressure.

In conclusion he pointed out that the gas industry had a better opportunity than any other industry of solving the fuel question, and with it the smoke problem, which are of such importance to the nation, and so placing itself in a stronger position than it now holds.

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5. *A Unit Gas-Producer for Steam Boilers.* *By* E. C. Mills.

Gas-fired boilers may be classified roughly thus :—

1. The gas a by-product from plant installed primarily for other purposes.
2. Grouped producers from which the unpurified gas is piped to boilers.
3. Grouped producers with partial or complete purification.
4. Coal-fired furnaces placed externally to the boiler.
5. Unit bituminous gas-producers delivering gases hot and unpurified direct to boiler.

[1] See *Journal of Gas Lighting*, September 14, 1915.

Class 1 gives very cheap steam, as capital charges are debited to other purposes, but is not applicable to ordinary or average steam plants.

Class 2 only applicable when fuel is extremely cheap.

Class 3. When the gas is produced only for steam boilers; it is only applicable to boilers of the Bone-Court type.

Class 4. This is hardly a gas-producer at all, but is named because many attempts have been made in this direction. It fails mainly by reason of destruction of brickwork under the intense heat.

Class 5. In this class is the Mills furnace.

All the above, as compared with the ordinary internal fire, have the advantage of not arresting the combustion process by temperature-reduction through contact with water-cooled plates.

Single gas-producers for metallurgical furnaces are well known and successful.

The aims of the inventor of the Mills furnace were :

1. It should not be too costly.
2. It must utilise the radiant heat of combustion.
3. There must be ample temperature to ensure complete chemical combination.
4. Access to boiler for examination and repairs must not be hindered.
5. The whole of the various gases given off by the fuel must be immediately burnt with their sensible heat of production in them.
6. Little or no excess air must be used.
7. All ordinary qualities of coal must be usable.
8. Attendance must not be excessive.

Dealing first with No. 6, above the usual allowance of excess air is absolutely necessary in the burning of fuel in solid or lump form by reason mainly of the mechanical difficulty of bringing each part of oxygen into intimate contact with its concomitant part of carbon or hydrogen at the right time and in the right place.

To do this in a metal water-surrounded box is an impossibility.

Slides showing outside, inside, and sectional views of the Mills producer will be shown. The action and control of the induced draught giving the separate air supplies for gas production and its combustion, the cellular construction of the roof and walls by which air for combustion is heated by the otherwise lost radiant heat of the producer; the means of withdrawing the whole to allow access to the boiler front; the special design of firebrick gas-and-air-mixing device and burner; the self-cleaning sight-hole appliance; the automatic fuel-feed; the arrangements for clinker-extraction; the flue-gas interceptors introduced, and other details of construction are shown on the slides, and examples and models of various parts will be on view.

The results of tests on a Cornish boiler, worked on an ordinary internal fire and with the Mills producer, with the same fuel in each case, and tested by the same expert, show a saving of about 50 per cent., and there was no smoke.

Tests on a Lancashire boiler with the Mills producer give high efficiencies and standardised evaporations ranging from 10·23 lb. to 11·47 lb of steam from 1 lb. coal, and on a comparison with another boiler fired with the same fuel but with the ordinary internal fire, the tests show a saving of about 18 per cent. in evaporation. In this case also there was an entire absence of smoke.

FRIDAY, SEPTEMBER 10.

The following Papers were read :—

1. *The Heating of Iron when Magnetised at very High Frequencies.* *By* N. W. McLachlan, *B.Sc., Eng.*[1]

This paper described experiments illustrating the heat produced when iron is magnetised by very high-frequency alternating currents, *e.g.*, 2×10^5 to 5×10^5 periods per second.

[1] See *The Electrician*, vol. lxxv., p. 877.

The magnetising current is obtained by using a Poulsen-arc generator connected across the town mains (240 volts). In order to demonstrate the extent of the losses, a magnetic heater or boiler, consisting of a solenoid wound on a glass tube containing water and a number of iron strips or wires, is inserted in the shunt circuit of the generator. A short time after the shunt circuit is closed the water begins to boil.

An experiment was also arranged to show the variation in permeability of iron with variation in temperature. A ring of Lohys (mild steel) is insulated with asbestos and wound with a number of turns of copper wire. This is connected in the shunt circuit of the generator. By passing a large current through the winding of the ring, thereby obtaining a strong magnetising force, the magnetisation losses are such that a rapid rise in temperature is produced, causing the iron to attain a bright red heat. The variation in permeability corresponding to the rise in temperature may be followed by observing the current in the shunt circuit and the voltage across the terminals of the ring. Data, including the watts lost per kilogram, are given which enable the changes to be followed.

2. *A Self-Adjusting Commutating Device.* *By* Professor Miles Walker.[1]

It is well known that a continuous current generator fitted with commutating poles (sometimes called inter-poles) will not commutate very heavy over-loads, owing to the magnetic saturation which occurs in the iron of the inter-pole. When the excitation becomes very great the saturation of the iron interferes with the proportionality that should exist between the current to be commutated and the commutating flux

The paper described a device tried at the Manchester School of Technology which automatically produces the right amount of commutating flux over very wide ranges of load So effective is the correcting influence, even where the diverter in parallel with the commutating pole winding is deliberately put out of adjustment, that, whether it be short-circuited or given a resistance equal to five times the proper resistance, the flux will be preserved at approximately the correct value.

Each brush (say, the positive brush) consists of two parts, one part, A, being slightly in advance of the other on the commutator, and lightly insulated from it. The winding on the commutating pole has twice as many turns as one would ordinarily have, and the cross-section of the copper conductor is only sufficient to carry one-half of the armature current. The part of the brush B may be connected through a diverter D, having the same resistance as the winding W, or the diverter may be dispensed with altogether. The direction of rotation of the machine is such that a point on the commutator passes first under B, then under A.

Assuming that the number of turns on the commutating pole is such as to give the right commutating flux when half current is passing through them, then it will be found that the current will divide evenly between brushes A and B, because the correct excitation of the commutating pole gives an even distribution of current over the face of the compound brush AB. If, however, the number of turns in W is too great, there is a tendency to over-commutation; that is to say, the current in B becomes greater and the current in A less. This has the effect of automatically weakening the commutating pole, and the pole remains of just such a strength as to bring about the required distribution of current between A and B.

It will be found on machines of ordinary rating, and more particularly on machines of very large rating, that the 'correcting' voltage between A and B necessary to bring about a suitable division of current between the two brushes is normally very small, being of the order of 0·5 of a volt, whereas the voltage which can be generated between A and B by a pole being too weak or too strong may easily amount to 5 volts or more. Thus a very little disturbance in the equality of loading on brushes A and B is sufficient to yield

[1] See *The Electrician*, vol. lxxv., p. 872.

the desired 'correcting' voltage. Curves are given showing how the correcting voltage varies with the load.

If for any reason the commutating pole tends to become too weak, owing, let us say, to the saturation of the iron of the pole, the induction of the armature coils carries the current forward to brush A, and tends to increase automatically the excitation of the commutating pole.

A 12 5 K.W. generator fitted with the device will be exhibited.

A 500 K.W. 500 volt rotary converter, built by the British Westinghouse Co., was fitted with the double brush gear, and it was found that with 3,000 amperes flowing the commutation was sparkless. The device is being at present installed on a 1,500 K.W. rotary converter, on which the commutating conditions would otherwise be rather difficult.

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3. *Electric Oscillations in Coupled Circuits—a Class of Particular Cases.* *By* W. Eccles, *D.Sc.*, *and* A. J. Makower, *M.A.*[1]

If three capacity-inductance branches are connected in parallel and vibrations are started in the system, these vibrations consist, in general, of two superposed simple harmonic vibrations of distinct frequencies. It is shown that if two of the branches are in tune a class of problem arises which has a very simple solution. Incidentally new formulæ are arrived at for calculating the frequency of the two oscillations in a pair of circuits coupled by inductance and capacity. It is shown also that for a single frequency to exist all three branches must be tuned to the same frequency. All the formulæ developed in the paper are verified by experiments extending over a wide range of values of inductance and capacity.

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4. *The Capacity of Aerials of the Umbrella Type.* *By* Professor G. W. O. Howe, *D.Sc.*[2]

In a paper read before the British Association at Sydney last year the author developed a method of calculating the capacity of radio-telegraphic antennæ. In addition to describing the method in general, curves and formulæ were given so that the capacity of aerials of standard types could be determined in a few minutes. The umbrella type, however, was not specially considered, and it has since been suggested to the author that the usefulness of the paper would be considerably increased if curves and formulæ could be given for aerials of this type. The method is briefly as follows: The whole aerial is assumed to have a uniformly distributed charge, and the average potential of the whole aerial under this fictitious condition is then calculated. It is assumed that if the total charge, while remaining unchanged in quantity, be allowed to have its own natural distribution, it will assume a uniform potential approximately equal to this fictitious average potential. The proximity of the earth is taken into account by the method of images. Tables and curves are given for aerials with from two to six ribs and for various angles between the ribs and the vertical. With these curves and those given in the original paper, each of the nine component potentials of any given aerial of the umbrella type can be read off and the resultant average potential determined. The method is then applied to two practical examples, one a simple aerial with six single-wire ribs, and the other a more complicated case in which each of the five ribs consists of a four-wire cage, the size of the wire being different from that used for the central vertical wire.

Tests on actual aerials have shown that the values of the capacity as calculated by the author's method agree with the measured values within the errors of observation and of estimation as to the allowance to be made for connecting wires, &c.

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[1] See *The Electrician*, vol. lxxv., p. 905.

[2] *Ibid.*, p. 870.

5. *A Note on 'Earth Resistance.'*
By Professor E. W. MARCHANT, *D.Sc.*[1]

This paper described a new method of expressing the effectiveness of earthing arrangements such as are employed for lightning-conductors, radio-telegraphic stations, and in connection with many electric-power distributing systems. The method consists in determining the length of the column of earthy material which, with a cross-section equal to the surface of the earth plates, would have the same resistance as the actual 'earth.' For a hemisphere embedded with its flat surface level with the surface of the ground, this 'equivalent length of earth' is easily seen to be equal to the radius of the hemisphere.

Some tests were described, made by the author at Liverpool on three 'earths' of different types, one being the water pipe system of the building.

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6. *Transformer Core Loss as affected by Triple Harmonics.*
By H. M. LACEY, *B.Sc.*, *and* C. H. STUBBINGS, *B.Sc.*[2]

This paper described experiments conducted in the Siemens Electrical Engineering Laboratory, King's College, London. The object of these experiments was to investigate the effect of triple harmonics upon the core losses in transformers.

An alternator giving approximately a sine wave was three-phase star connected to a three-phase choking coil. The star centres were also connected through a switch. Current-measuring resistances were inserted in the neutral and one of the outer leads. Voltmeters and ammeters were also inserted as required.

Two experiments were made:

(1) With the switch in the neutral wire open.
(2) With the switch in the neutral wire closed.

In each case the wave forms of phase amperes, phase volts, and in the second case amperes in the neutral wire, were taken by means of a Kelvin quadrant electrometer and a contact-maker. It was found upon analysing the various wave forms that in the first case there was a 48·9 per cent triple harmonic in the volt curve but practically none in the current curve. In the second case there was practically no triple harmonic in the volt curve but 48·2 per cent. in the current curve; also the wave of current in the neutral wire was very nearly a sine wave of triple frequency, and having an amplitude of approximately three times that of the triple harmonic in the current curve. This shows that the existence of a neutral connection enables a triple harmonic to exist in the current curve, and also that the suppression of this harmonic from the current curve forces it into the volt curve. Using these curves, the induction curves for the two cases were drawn, and from these the hysteresis loops (including eddy current losses) were obtained. The areas of the two loops were measured, and the ratio of the areas case 1 : case 2 was found to be 0·775, thus showing that by insulating the star centres a saving of 22·5 per cent. in the core loss is obtained, the voltages being equal.

The watts supplied in the first case were 24·3 per cent. less than in the second case, the average watts being found from the curves. The results of these experiments point to the fact that from the point of view of core losses the star centres in three-phase systems should be insulated.

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7. *Exposure Tests of Light Aluminium Alloys.*
By Professor ERNEST WILSON.[3]

The physical properties of certain light aluminium alloys have formed the subject of reports during the last fourteen years. In order to investigate the

[1] See *The Electrician*, vol. lxxv., p. 882.
[2] *Ibid.*, p. 874. [3] *Ibid.*, p. 886.

influence of exposure to London atmosphere a specimen of each alloy has been placed on the roof of King's College, London. All the specimens are in the form of wire 0·126 inch (3·2 mm.) diameter.

Commercial Aluminium.—A specimen has steadily increased its electrical resistance to 17·2 per cent. in thirteen years. *Copper.*—It has already been pointed out that the electrical resistance of the copper series in a given time increases with the percentage of copper. One specimen containing 2·61 per cent. of copper had so far corroded in 1911 that it broke quite easily. Another specimen containing 1·86 per cent. of copper has now so far corroded as to become practically useless as an electrical conductor. The tests emphasise the opinion already expressed that alloying commercial aluminium with copper except in small quantity is not to be recommended. *Copper-Manganese.*—Three alloys containing from 0·02 to 0·09 Cu and 0·05 to 1·78 Mn have steadily increased their electrical resistance to about 10 per cent. in fourteen years. The specimen with the highest percentage has a breaking load of 35,000 lb., and is apparently in good condition. *Copper-Nickel.*—A specimen containing 1 08 per cent. Cu and 1·29 per cent. Ni has somewhat diminished its electrical resistance—the percentage being now 12·4, as against 19 4 in 1908 Its breaking load was 45,900 lb. before exposure. *Copper-Zinc-Nickel.*—One specimen containing 0·11 Cu, 1·77 Zn, 2 01 Ni, has diminished its electrical resistance as shown by the following figures:

Year	1901	1903	1904	1908	1911	1913	1915
	962	995	1013	1285	1125	1102	1102

Copper-Manganese-Magnesium.—The alloy known as 'Duralumin' is stated to contain about 0·5 Mg, 3·5 to 5·5 Cu, 0·5 to 0·8 Mn. A breaking load as high as 90,000 lb. can be obtained according to treatment The specimen exposed has steadily increased its resistance to 9·6 per cent. in four years. It is, however, so brittle that a small loop cannot be bent without fracture.

The author was unfortunately unable to report on the copper specimen, as it had been stolen from the roof.

SATURDAY, SEPTEMBER 11.

The following Papers and Report were read:—

1. *Recent Improvements in the Traction of Vehicles.* *By* T. H. Brigg.

The author for more than a quarter of a century has made his life-study the subject of mechanical forces relative to traction, and has applied these principles to various contrivances, such as shaft-supporting appliances, the 'Plywell' for poled-vehicles, and other mechanical contrivances. Recently the War Office placed at his disposal the drawings of artillery and general service wagons in order to give him an opportunity of showing how the draught of these vehicles could be improved. His attention also having been directed to the machine-gun, he has devised a means by which these weapons can be more rapidly transported, and manipulated with greater ease to the gunners and with more deadly effect upon the enemy, while at the same time both gun and gunners are protected by armour-plate. His paper is a description of the new mechanical appliances which he has devised as a result of the above opportunity.

The salient feature involved in the easy haulage of artillery and limber-coupled ammunition and general service wagons is precisely the same for civil as for military purposes; and it remains the same regardless of whether traction be effected by men or by horses. It will be found upon investigation that conditions which conduce to the greatest comfort and efficiency in the transport of man by his own muscular effort are identical with those which conduce to the comfort and efficiency of transport by horses and other living creatures, an illustration of which are the mechanical movements of the swan, which are effective in producing the least possible rise and fall of its body with the greatest possible thrust in the desired direction of motion—a movement not hitherto described,

The new system of traction for limber-coupled wagons is one which causes the limber and the carriage to constitute two mechanical levers which, at such times as the resistance to traction is small, carry a part of the weight of the animal, while when it is great, they cause an automatic transference of weight from the wheels to the animal; thus securing an ever-varying virtual angle of traction. The same effect is automatically brought about to the advantage of the horse by each of the inventor's new appliances.

The same conditions are obtained in the case of man-hauled vehicles.

The paper was illustrated by working models and diagrams.

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2. *Report on Complex Stress Distribution.*—See Reports, p. 159.

3. *The Strength of Iron, Steel, and Cast-iron Struts.* *By* Andrew Robertson, *M.Sc.*

A series of experiments on solid free-ended centrally-loaded struts has been carried out in the Engineering Laboratories of the Manchester University during the last two years. They lead to the following conclusions:

1. For all the struts tested the collapsing load was in accordance with the values calculated from Euler's formula, except for struts so short that the average stress produced by the theoretical load was above the elastic limit of the material.

2. In the case of the shorter struts the material tested may be divided into two classes:

(*a*) Materials having no appreciable drop of stress at yield (cast iron and bright-rolled steel). For such materials, Southwell's formula—of which Euler's is the particular case for wholly elastic material—gives the collapsing load for all lengths.

(*b*) Materials having a decided drop of stress at yield (mild steel, wrought iron, and high tensile steel). For such materials Euler's or Southwell's formula applies for all lengths for which the average stress calculated is less than the elastic limit. Southwell's formula applies between the elastic limit and the yield point, and for the shortest struts the collapsing load is equal to the yield stress multiplied by the area.

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4. *The Calculation of Torsion Stresses in Framed Structures and Thin-walled Prisms.* *By* Professor Cyril Batho, *M.Sc., B. Eng.*[1]

In designing a double track cantilever bridge with suspended span, it is necessary to calculate the stresses arising in the suspended span due to unsymmetrical live loads on the cantilever and anchor arms. It is also sometimes of importance to determine the stresses in an ordinary truss-bridge, braced arch or other framed structure on four supports due to unequal settlement of the supports. Similar problems arise in connection with erection travellers carrying unsymmetrical loads, &c. The stresses arising under such conditions may be termed torsion stresses. The calculation of these may be considerably shortened by the use of the following theorems.

If a framed structure consisting of two parallel trusses, similar in outline and connected by lateral bracing, be subjected to unit forces at the corners forming a pair of equal and opposite couples in the planes of the two trusses respectively, the shear perpendicular to the plane of the trusses is constant throughout the lateral system and equal to the area of the base of the framework divided by twice the area of one of the trusses. The theorem may be extended to include thin-walled prisms, and in its most general form may be stated thus: If a hollow cylinder or prism, either continuous walled or of framework and having plane ends perpendicular to its length, be subjected to a twisting moment by couples in the planes of its ends, the total longitudinal shear is everywhere constant and equal to the twisting moment multiplied by

[1] *See Engineering*, October 15, 1915, p. 392.

the length of the cylinder and divided by twice the area of one of its ends. Three examples are considered in the paper:

(i) A bridge having parallel chords and panels of equal length.

(ii) A thin-walled rectangular box.

The results in these cases are shown to be in agreement with those given by other and longer methods.

(iii) The torsion stresses in the suspended span of a bridge similar in design to the New Quebec bridge.

In this example it is shown how the stresses in the lateral system may be calculated immediately by use of the above theorem, and how the stresses in the main trusses may be found by means of a short graphical process.

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5. *An Inquiry into the Possible Existence of Mutual Induction between Masses.* *By* Professor MILES WALKER.

The closeness of the analogy in the behaviour of matter in motion and electricity flowing in a circuit leads us to inquire, 'Is there any action between masses analogous to the mutual induction between electric circuits?' If we accelerate a fly-wheel does it produce any force upon an adjacent co-axial disc? It is quite possible that a small force of the kind might pass unnoticed if not specially looked for, just as the gravitational attraction between two movable bodies would ordinarily escape observation.

The author described and exhibited apparatus constructed at the Manchester School of Technology in 1912 for the purpose of finding out whether any force of the kind is observable.

A steel fly-wheel, A, 56 cms. in diameter and 11 cms. thick, is mounted on a vertical shaft and driven by an electric motor. Above the fly-wheel is suspended a disc, B, 51 cms. in diameter, made of very pure porcelain, weighing about 10 kilograms. The suspension is made of two round steel wires each ·025 cm. in diameter. The length of the suspension is 21 mètres. The distance between the bifilars is about 0·15 cm. The torsional control on B is extremely small, amounting to only 28 dyne-cms. for a deflection of 1 radiam. The angular swing of B upon its principal axis has a natural period of 2,460 seconds. A mirror is attached to B, which enables the movement to be accurately observed on a scale at 6 mètres distance. A movement of ·01 cm. on the scale corresponding to a deflection of 1/12,000 of a radiam can be estimated, so that one can observe the effect of acting on the edge of the disc with a force amounting to only 10^{-11} of the weight of the disc. The paper described some of the precautions taken to avoid the effect of accidental disturbances.

The procedure in making the experiment is as follows: The disc B is brought as nearly as possible to rest. The fly-wheel A is then rapidly accelerated (say, anti-clock-wise) and run up to a speed of 2,700 r.p.m., so as to give an impulse to B if that were possible. The speed is then maintained constant for one-half the natural period of the swing of B. The fly-wheel is then rapidly slowed down and the direction of rotation reversed and the speed increased to 2,700 r.p.m. (clock-wise). This is repeated several times, so as to set up resonance in B.

In the early experiments made in 1913 it was found that if there were any effects of the kind looked for they were of an exceedingly small order, and that the observed movements of B were mainly due to accidental disturbing forces. At this time it was possible to assert that the ratio $\frac{B^{mon}}{A^{mon}}$, the change in the angular momentum of B to that of A, was certainly less than $2{\cdot}3 \times 10^{-8}$.

In the later experiments the chief aim was to diminish the disturbing forces as far as possible, so that the negative result might be stated with the smallest possible limit of error.

The introduction of a suspended screen and other refinements so improved the steadiness of B while A was running that we can now state that the ratio for this apparatus is less than 5×10^{-10}.

Section H.—ANTHROPOLOGY.

President of the Section.—Professor C. G. Seligman, M.D.

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address :—

It is impossible to pass to the subject of my address without first referring to the heavy losses which the Teutonic lust of power has inflicted upon our science, no less than upon every other department of humane and beneficent activity. Whatever loss we may yet be called upon to endure there can hardly be any more regrettable than the death of Joseph Déchelette, whose acknowledged eminence makes any detailed account of his labours superfluous. I will but mention his *Manuel d'Archéologie*, a work of rare lucidity, which though unfinished (the pity of it) will long be authoritative upon European prehistory and archæology. His valour was no less than his erudition, for though his age exempted him from all military duties, he insisted on taking his place at the head of his old company of Territorials, and was killed last October while leading his men in a charge that carried the line forward 300 yards. How he died may be learnt from the official army order quoted in *L'Anthropologie* (vol. 25, p. 581). We have also to mourn the death of Robert Hertz, a regular contributor to *L'Année Sociologique*, and of Jean Maspero, son of Sir Gaston Maspero, an authority on the Byzantine period and Arabic geography.

The other men whose premature death we deplore belong for the most part to that brilliant band of French soldier-explorers to which African ethnography owes so much. Captain René Avelot, whose name will be known to every reader of *L'Anthropologie*, was also the author of important papers in *La Géographie* and other geographical periodicals. He had hoped to devote himself entirely to ethnological work, and at the outbreak of war was about to publish a series of studies on the natives of the French Congo, Darfur, and Wadai. Before going to the front he arranged for the publication of these, even in the event of his death.

Captain Morice Cortier, a geographer and an explorer rather than an ethnologist, was engaged at the time of his death in preparing a work on the prehistory of the Sahara.

Captain Maurice Bourlon received his scientific training in the Dordogne. He conducted excavations in the neighbourhood of Les Eyzies, where he made a number of discoveries, and brought to light some remarkable specimens of palæolithic art.

We dare not hope that the foregoing list is final, and while mourning their loss we cannot pay greater honour to their memory than by taking up the burden they relinquished in the hour of their country's supreme need.

In my address I shall endeavour to outline the early history of the Anglo-Egyptian Sudan from the standpoint of the ethnologist, and thus indicate some of the lines upon which future research may most usefully proceed. Fortunately the Sudan is one of those areas in which the site and scope of work may be selected from the point of view of immediate scientific interest, without any grave dereliction of duty. There is not the danger so frequently met with, in the

Pacific for example, of finding that civilisation has come stealthily and swept away the greater part of the old order. The Sudan has not been civilised to such a point that the ethnologist need feel it his bounden duty to visit the most sophisticated areas in order to record everything that is in danger of being lost. If I seem overbold in trying to present a summary account of so vast an area, I can plead certain extenuating circumstances. Firstly, I had the good fortune to be asked by the Sudan Government to conduct a small ethnographic survey for them, in the course of which I have spent two winters in the field; secondly, although it is nearly twenty years since the reconquest of the Sudan, the amount of ethnographical material which has accumulated is far less than might have been expected. Nowhere has there been any intensive study of even a single people, though conditions are as favourable as could be desired in at least three quarters of the country. It would be an interesting, if melancholy, task to try to determine why so little has been done. Certainly the failure is not due to lack of interest on the part of the Sirdar and his Council, for, apart from the funds provided for my expeditions, the Government has paid the expenses of publishing the only considerable work of serious scientific interest dealing with Sudanese tribes that has yet been written by any of its officers. It is worth noting that archæologists have been more energetic than ethnologists, partly no doubt owing to the stimulus provided by the discoveries of the Nubian Archæological Survey, but, even apart from this, more interest seems to be taken in the ancient history of the country than in its living races.

Surprisingly little is yet known of the prehistory of the Anglo-Egyptian Sudan. No implement of river drift type appears to have been found, and while admitting that this may be due to incomplete exploration, the fact seems of some significance considering the abundance of specimens of this type which have been found on the surface in Egypt, Southern Tunisia and South Africa. With regard to implements of Le Moustier type, I may allude to certain specimens which I have myself collected from two sites, namely from Beraeis in north-west Kordofan, situated on a sandy plateau at the foot of Jebel Katul between two small spurs of the main rock mass, and from Jebel Gule in Dar Fung. At the former site I found a number of roughly worked unpolished stones near the foot of the hill between the village and the burial ground, and also within the latter. The majority are moderately thin broad flakes, showing a well-marked bulb of percussion, and little or no secondary working; other specimens are shorter and stouter. One surface is flat and unworked, the opposite curved surface shows a number of facets separated by rather prominent crests, all except the central facets sloping more or less steeply to the working edge. In some specimens the crests are sufficiently prominent to give a somewhat fluted aspect to the slope and a crenelated edge, one portion of which often shows signs of having been worn down and retouched. These implements, which I had suspected might have been Aurignacian, were considered by M. Breuil to belong to the Moustierian period, and he referred to the same period and industry some thick, fluted and engrailed scrapers from Jebel Gule, which I have described as resembling the palæolithic discs from Suffolk and other localities (**19.** 211), as well as some implements of other forms which presented a palæolithic facies. While the Beraeis stones are so rough that they may perhaps be rejects, this does not apply to the specimens from Jebel Gule. Besides the disc and Moustierian points there is one implement which M. Breuil regards as a true, but much worn, *coup-de-poing* of Moustierian age. Whether all these really date from the Moustierian period or not, certain of the specimens from Jebel Gule show a surprising resemblance to South African specimens figured and described by Dr. L. Peringuey as of Aurignacian type (**14** Pls. xvi. $\frac{1}{3}$, xi. 60, xviii. $\frac{1}{3}$), or in other words of the Capsien type of Tunisia.

Evidence concerning the later Stone Age is furnished by a number of finds made on widely scattered sites; but though no explanation can be offered it should be noted that no stone implement of any kind has been recorded from the Red Sea Province, although it is one of the best known parts of the Sudan, and has been the scene of considerable engineering efforts. This is the more remarkable in view of the geographical features of the country; the absence of forest, the weathered plateaux, the valleys filled with deposits through which innumerable wadis have been cut, all suggest that if stone implements existed some at least should have come to light. Much interest attaches to the distribu-

tion of ground stone axes in the Nile valley. While there is probably no museum with any pretence to an Egyptian collection which has not a number of these, and though they can be bought in almost every curio shop in Cairo, I have been unable to find any record of their discovery in a tomb group or undisturbed burial in Egypt; so that considering the number of prehistoric burials that have been examined, it can be said that they were scarcely if at all known in predynastic Egypt. On the other hand, they are common in Nubia, where a number have been found in predynastic and early dynastic tombs (**2** Pl. 63). Many examples have come from Meroe, and I believe that specimens occur on every site of neolithic date in the Sudan. They have certainly been found at Jebel Sabaat, at Jebel Geili 90 miles east of Khartum, at Jebel Gule and at Faragab. Moreover, the rock faces on which they were ground have been found both at Jebel Gule and Jebel Geili. We may therefore attribute a southern source to the ground stone axes of the Nile valley, and in the light of our present knowledge regard them as of Negro origin. This view is supported by the results of recent work on the prehistory of the Sahara. Gautier, who has devoted much time to the ethnography of the French Sudan, points out that while at the end of the neolithic period the northern Sahara had a stone industry characterised by unpolished implements of Egyptian affinities, in the central and southern Sahara the typical implement was the polished axe, and that this was of Sudanese Negro origin (**7**, 326). That the boundary of the two provinces seems to have coincided roughly with the present southern boundary of Algeria, *i.e.*, that the Berber-Negro frontier was then some 1,000 kilomètres further north than it is at present, is in no way opposed to this view. Perforated discs or rings and hollow conical and spherical stones, all ground in the usual neolithic style, have been found, notably at Meroe, on Jebel Haraza (W. Kordofan) and at Jebel Geili, where I believe stone discs and axe heads can be definitely associated together. Besides the types already alluded to Jebel Gule yielded a large number of pygmy implements of quartz, carnelian, and hornstone. These are similar to those found in South Africa and attributed to Bushmen, and there is reason to believe that this industry also existed at Faragab, where the innumerable disc beads of ostrich egg shell were probably bored with more or less worked up slivers of quartz

The distribution of stone arrow heads in the Nile valley is also of much interest, but the data are as yet insufficient for discussion. It may, however, be worth while to point out that the transverse arrow head with its chisel-like edge cannot be of Negro origin, although the wooden figures of Negro bowmen from the tomb of Emseht, a general of the XI. dynasty, are armed with arrows with heads of this form, and the same type of arrow head is in use to this day among the tribes of the Kwilu and Kasai districts of the Belgian Congo.

Some mention must be made of the existence of stone monuments of megalithic type in the Sudan, although their number is small and their origin obscure. There is a monolith about two mètres high on the plateau overlooking the Khor el Arab, near the Sinkat-Erkowit road, to which tradition says Mohammed tied his horse. Another monolith of much the same dimensions has been described and figured by Crowfoot from Isa Derheib inland from Akik (**4** Pl.). At present there seems no reason to attribute any great antiquity to these stones; presumably they are connected with the upright stones and 'stelai' of Axum. Probably other rude stone monuments will be found in the Red Sea Province; indeed, I have heard of such, though the information was never very precise. It is, however, worth noting that typical dolmens do occur in the Madi country in the southern Sudan (**26**, 123).[1]

[1] When the time comes to estimate the significance of the Sudanese monuments of megalithic types, it will be necessary to remember that, although uncommon, they do occur in Egypt. Indeed, Déchelette has suggested that their rarity in Egypt is only due to their having been nearly all destroyed. Meanwhile it may be noted that de Morgan has published the drawing of a stone circle at Jebel Genamieh in the desert to the east of Edfu; that N. de G. Davies found perfect miniature dolmens or cists at Tel el Amarna; that somewhat similar structures containing human remains have been described by Schweinfurth near El Kab; and that I have found them on the high desert plateau a few miles north of Abydos.

Although neither in structure nor form megalithic, I may here refer to a type of stone monument some 80 feet long and about 5 feet high occurring in some number in the neighbourhood of Erkowit, in the Red Sea Province. The whole is constructed of stones without any cement or mortar; the face consists of a limiting wall of more or less flat slabs of local rock, while the spaces between the containing walls are filled in with smaller fragments. Each of these monuments may be considered as consisting of three main elements—viz. (i) an oblong rectangular portion, (ii) two oval masses to each of which is attached an expansion shaped somewhat like a fish's tail, and (iii) the curved walls uniting the other elements. Their orientation is definite within certain limits, while each oval element is interrupted at a constant point in its circumference by the interposition of from two to four upright slabs. There is no chamber or space behind these stones, but from their constancy and the uniformity of their position it is obvious that they must have had a perfectly definite significance to the builders, and on account of their similarity to the false doors of Egyptian monuments I venture to call them 'false entrances.' The whole structure is quite unlike any others of which I have been able to hear, nor did the excavation of one much damaged example throw any light on the problem, but the false entrance suggests a funerary purpose and an Egyptian origin. In date they are probably mediæval, and may certainly be taken to antedate the spread of Mohammedan influence which was becoming dominant towards the middle of the fifteenth century (**20**).

The only rock pictures as yet found in the Sudan are in northern Kordofan. For the most part they are outlined in red or blackish pigment, but a few examples occur chipped on lumps of granite, on the hillside at Jebel Kurkayla in the Jebel Haraza *massif*. These figures are very rough, and the examples reproduced by H. A. MacMichael all represent camels (**11**). Drawings with pigmented outlines are found on Jebel Haraza and Jebel Afarit, and from the artistic standpoint seem to form two groups. To the first belong rough but spirited sketches of men on horseback, camels, and giraffes The workmanship of the second group is rougher and much less vigorous; it includes representations of camels, men on horseback, and men marching or dancing carrying the small round Hamitic shield. This, together with their general resemblance to the 'Libyo-Berber' rock pictures of the southern Sahara, indicates a comparatively recent date for these drawings. Moreover, MacMichael notes that the work is faint and indeterminate, and that there is no trace of graving; in other words, the neolithic tradition has not persisted. Probably they are more recent than the stone discs and hollow conical and spherical stones found on Jebel Haraza to which I have already referred.

One of the most difficult questions arising in connection with the Sudan is that of Ancient Egyptian influence. Its existence may be readily granted, but what of its extent and duration? For while it is a platitude to say that a great and powerful state with a uniform tradition lasting for thousands of years cannot but have influenced the countries on every side, it must be confessed that where history fails the evidence is often extremely difficult to interpret. Every custom which at first sight seems to betoken Egyptian influence must be closely examined, and the evidence carefully sifted, to determine whether it may not have had its origin in the older and more generalised Hamitic culture of northern and eastern Africa. In discussing the value of the data upon which ideas and customs are to be traced back to an Egyptian origin, it is important to remember that general resemblances, either in widely distributed forms of social organisation and belief (*e.g.*, matrilineal descent, cult of the dead, &c.), or in widely diffused technical devices (*e.g.*, bow and arrow), cannot be admitted as good evidence. Whatever the future may bring, I do not think that in the present state of anthropological science even extreme and unusual beliefs and devices (which at first sight seem so strikingly convincing) should be considered as proof of common influence; otherwise it would be necessary to admit, immediately and without consideration, a cultural relationship between Papua and Central Brazil on the evidence of the phleme-bow, and between England and the Malay States on that of the fire-piston.[2] It is only when there is a considerable consensus of

[2] The distribution of the fire-piston in the East and its discovery as a 'scientific toy' in Europe has been discussed by Mr. Henry Balfour in *Anthropological Essays presented to Edward Burnett Taylor.*

greement in underlying ideas and (or) in highly specialised customs or devices, hat we are justified in considering an Egyptian origin, and even then it is ecessary to bear in mind the possibilities of common ethnic origin and of 'con-ergence.' It is obvious that under these conditions facts will be differently nterpreted, and opinions will vary within wide limits, while new discoveries ıay at any moment disturb views hitherto regarded as well founded.

Although in this address I propose generally to confine myself to the area ncluded in the Anglo-Egyptian Sudan, yet in considering the question of Egyptian influence in Negro Africa I shall overstep these limits. The reasons or doing so are, I think, obvious. The data will not be abundant, and will ıot be restricted to the Anglo-Egyptian Sudan, while instances occurring out-ıde that area will possess the same evidential value. Moreover, the records from he Belgian Congo, for example, are more numerous, while recent work in the ıorth-west of Africa has provided material of much value from this comparatively new point of view. Thus, I shall not hesitate to cite West African nstances, even though it is probable that the cultural drift responsible for them crossed North Africa and travelled down the west coast. It must not be forgotten that North Africa was permeated with Egyptian influence during the last ew centuries B.C. Evidence for this statement might be drawn from many sources, but I will cite only one, that offered by the coinage, which is particularly convincing. In the third century B.C. many Carthaginian electrum and bronze coins bore the disc and uræi (**12**, ii. 85, 93); a little later the coins of Numidia also bore Egyptian symbols, while in the first century B.C. those of Bogud II. of Mauritania (50-38 B.C.) were stamped with the winged disc. One of his successors, Juba II., married an Egyptian lady, Cleopatra Selene, daughter of Mark Antony and Cleopatra, and, while his coins bear the uræus, those struck in her name bear the sistrum, the crown of Isis, and such Nilotic animals as the crocodile and hippopotamus (**12**, iii. 17, 95, 105, 110). These facts become the more significant when it is remembered that the coinage of the Ptolemies, the only pre-Roman coinage that Egypt had, was derived from the Greek and bore no Egyptian symbols.

Some will have it that we are faced with yet another difficulty; an Egyptologist has recently produced a work showing evidence of much patient research, in which he argues that a number of bloodthirsty rites, which he states occurred in predynastic and early dynastic Egypt, are closely related to those practised in West Africa at the present day, and indicate that the Egyptian religion is essentially 'African' in origin. His use of this word seems to indicate that he employs it as the equivalent of 'Negro,' though the latter word is never actually used. I believe that there is good and valid evidence against this view, both on the physical and the cultural side. All the work of the Archæological Survey of Nubia confirms the idea that the predynastic Egyptians were not even negroid, and it has extended this conclusion to the early Nubians who lived during the first three or four Egyptian dynasties. On the cultural side the evidence, though less absolute in that the data cannot be so objective as those supplied by long series of physical measurements, is none the less clear. It is generally held that the *sed* festival of Ancient Egypt was a survival, in a much weakened form, of the ceremonial killing of the king, and that its essential element was the identification of the king with Osiris. It was an important ceremony which persisted through the whole historic period, and was so much to the Pharaohs' taste that it was enacted no less than six times during the reign of Rameses II. The oldest known representation of the ceremony is that on the mace head of King Narmer (Menes). The king is seated in a shrine at the top of nine steps, dressed as Osiris, and holding the flail. On one side in front of the king are a number of standards, the first bearing the jackal Upwawet, 'the opener of the ways,' described on the seal of King Zer of the I. dynasty as 'he who opens the way when thou advancest towards the under-world.' The seal shows King Zer as Osiris preceded by Upwawet and 'the *shed-shed* which is in front,' the emblem of lightness or space. It is well known that kings are still killed ceremonially in Negro Africa at the present day; there are also rites which seem to be weakened forms of the same ceremony in which the king is permitted to survive. Assuming the above hypothesis of the origin of the *sed* festival to be correct, it cannot be seriously argued that the early Egyptians took over the custom from

the Negroes, at a time when Negro influence was so slight that no considerable amount of intermarriage had occurred. A custom which if it were not originally Egyptian would have introduced a totally new outlook on the world, and would have been intensely unpopular with the ruling powers.

With regard to the mode in which Egyptian influence was exerted on the Sudan there are three main routes along which we might expect to find its traces. The first is southwards along the Nile, the other two are to the west; one route at first following the Mediterranean coast but broadening westward as conditions become more favourable, the other running south-west through the oases and so communicating with Darfur and the Chad basin. Yet another route has been suggested by Sir Harry Johnston, namely, through Abyssinia and Somaliland, presumably reaching them *via* the Red Sea (**8**, 487). Perhaps it was by this route that the sistrum, still used in the church festivals, reached Abyssinia

The extension of Egyptian rule up the Nile Valley can be traced from the earliest times to the XVIII. dynasty. But although after this Egyptian domination becomes less marked, Egyptian influence had become so firmly established that the culture of the states in the Nile Valley had a predominantly Egyptian tinge;[3] first Napata, then Meroe, and then further south the states which we know later as the Christian kingdoms of Dongola and 'Alwah

On *a priori* grounds the Nile route might be expected to be the most worn and the easiest to trace. For thousands of years Egyptian and Negro were in contact on the middle reaches of the great river, so that at least one great negroid kingdom arose; and though to this day a Negro dialect is spoken as far north as Aswan, yet at the present time there does not seem to be a single object or cultural characteristic which unequivocally can be said to have reached the zone of luxuriant tropical vegetation by way of the Nile Valley. The evidence for the earliest spread of Egyptian influence is set forth in the *Reports of the Archæological Survey of Nubia*, and, referring as it does to the country north of Wady Halfa, is outside the scope of this address. Yet I cannot leave it altogether unnoticed, since it is intimately related to the discoveries recently made by Professor Reisner at Kerma in Dongola Province beyond the Third Cataract. (**17**.) In the Reports, Professor Elliot Smith shows that beyond Aswan, as far south as exploration has proceeded, the basis of the ancient population from the earliest times to the end of the Middle Empire was essentially of proto-Egyptian type, and that this type became progressively modified by dynastic Egyptian influence from the north, and Negro and Negroid influence from the south. As a result the Nubians contemporary with the New Empire present such pronounced Negroid characteristics as to form a group (the C-group) which stands apart from its Nubian and Egyptian predecessors (**2**. Bulletin iii. 25.) The recent discoveries at Kerma, which include fragments of alabaster jars with the names of kings of the VI. and XII. dynasties and also seal impressions of the Hyksos period, have shown that here was a fort or trading post certainly occupied during the Hyksos period, and probably as far back as the VI dynasty. It is the remains of the Hyksos period that are especially interesting. Professor Reisner describes a people who razed the buildings of their predecessors, and buried their dead in the débris, who battered the statues of Egyptian kings of the XII. dynasty, and whose funerary customs were entirely un-Egyptian. Each burial pit contains a number of graves in every one of which several bodies had been interred. The chief personage lies on a carved bed; 'under his head is a wooden pillow; between his legs a sword or dagger; beside his feet cowhide sandals and an ostrich-feather fan. At his feet is buried a ram, often with ivory knobs on the tips of the horns to prevent goring. Around the bed lie a varying number of bodies, male and female, all contracted on the right side,

[3] The early Ethiopian kings used the Egyptian language and writing for their records; it was only towards the end of the Meroitic period, after the downfall of Egypt, that the Meroitic language was written. A special hieroglyphic alphabet founded on the Egyptian may date back to the third century B.C., but the actual Meroitic script is later than this; Crowfoot indeed argues for so late and short a range as from the middle of the second to the fourth century A.D. (Griffith, *The Meroitic Inscriptions of Shablûl and Karanog*, chap. ii.).

head east. Among them are the pots and pans, the cosmetic jars, the stools, and other objects. Over the whole burial is spread a great ox-hide. . . . Several had their fingers twisted into their hair or had covered their faces with their hands. One woman had struggled over on her back and was clutching her throat. But most of them lay composed as if minded to die quietly, according to the custom of their fathers.' (**17**, xii. 24.) Reisner could not observe any marks of violence, but, judging from the contorted positions of some of the bodies, thought that they had been buried alive. The remains from these burials have been examined by Elliot Smith, who states that the skeletons surrounding the bedstead are those of folk of proto-Egyptian and Middle Nubian (C-group) types, while those on the beds belonged to typical New Empire Egyptians, such as lived in the Thebaid at this time. (**23**, 228.)

The first historical capital of the Sudan was Napata, the mediæval Merowe or Merawi, near Jebel Barkal, between the 19th and 20th parallels of latitude, a few miles south of the Fourth Cataract. Napata was certainly an important place in the XVIII. dynasty but how much earlier is uncertain. In the XX. dynasty the high priest of Ammon assumed the viceregency of Nubia, and even Rameses XII., the last and feeblest king of this dynasty, retained Thebes and Nubia though the delta had become independent. Remembering the troubles and revolts of the XXI. and XXII. dynasties and the expulsion of the nobles of Thebes we may believe that the priestly families of Thebes were forced to flee to the more remote parts of Nubia, and so set up at Napata a kingdom which, in theory at least, reproduced the theocracy of Ammon at Thebes. The first recorded lord of this new kingdom was Kashta, whose son Piankhi succeeded him about 741 B.C. and by 721 B.C. had conquered and garrisoned Egypt almost as far north as the Fayum. Later he received the submission of the Lords of the Delta, and was succeeded by his brother Shabaka, who ruled all Egypt and founded the XXV. (Nubian) dynasty which lasted at least fifty years. Thus Napata was Egyptianised, and being a great trading centre cannot but have influenced profoundly the country to the south, so that when Meroe was founded in the eighth century B.C. the ruling influence must have been Egyptian. The mission sent by Nero to explore the Nile reported that Meroe was ruled by a Queen Candace, whose predecessors had borne that name for many generations. (**16**. Bk. vi. chap. 35.) It is uncertain whether the Candace of Nero's time was one with the Candace (Kantakit) who was buried in a Meroe pyramid, or whether the latter was identical with the queen who attacked Egypt during the reign of Augustus. However the matter may stand, we know of two if not three queens bearing the same name. Yet, since the monuments show that a king was generally the head of the state, Pliny's assertion requires qualification; moreover, there is the perfectly definite reference to King Ergamenes slaughtering the priests who, as was the custom, had determined his death. In both statements I cannot but see examples of Egyptian theocratic influence. Nor are they mutually destructive if it be remembered that the throne might, and often did, pass in the female line, and that this practice was known to be in full force during the XVIII. and later dynasties.[4]

It would be entirely consonant with the policy of the priests of Ammon to take advantage of the spirit of the *sed* festival, the rite of ceremonial Osirification practised by the Egyptian kings, in order to obtain for themselves absolute political control. This would be easier if among the barbaric tribes in southern Nubia the king was ceremonially killed as he recently was in Fazogli, and as he still is among the Nilotes. That the practice of slaying the king was no new priestly device is, I think, clear from the account given by Strabo, and though I have no space to analyse this, I may point out that it accords well with our knowledge of the divine kings existing in the Nile valley at the present day, or in recent times. Strabo's description makes clear how relatively narrow

[4] Paynozem I. of the XXI. dynasty married the daughter of the Tanite king, Pesibkhenno I. and Sheshonk the founder of the XXI. dynasty legitimised his line by marrying his son to the daughter of Pesibkhenno II., the last king of the preceding dynasty. So, too, in order to hold the treasure of Ammon at Thebes, Piankhi caused Shepnupet the daughter of Osorkon III., sacerdotal priestess of Thebes, to adopt his sister-wife Amenardis.

was the stream of northern civilisation which penetrated Black Africa by way of the Nile valley. But even this civilisation did not come with a steady flow; when Egypt prospered under the early Ptolemies Meroe prospered; as Egypt decayed Meroe fell into the wretched condition recorded by Nero's officers; and even before this Candace could assert that neither the name nor condition of Cæsar was known to her. (**24**, Bk. xvii. chap. 1.) As northern influence lessened, and the power of Meroe decayed, the black element would preponderate more and more, so that the travellers who visited Ethiopia told a story of barbarism and utter stagnation. The mode of life of the Ethiopians was wretched, they were for the most part naked wanderers, moving from place to place with their flocks. Even in the cities along the river banks the houses were as often made of wattle and wood as of bricks. Although they had grain from which they prepared beer, they had no fruits or oil, using butter and fat instead, and lived upon roots and the flesh and blood of animals, milk and cheese. (**24**, Bk. xvii. chap. 2.) Beyond the immediate neighbourhood of the river was a region of savagery, with inhabitants for the most part known by mere nicknames, root-eaters, fish-eaters and so forth. But even in the earlier and better days of Meroe there is evidence that suggests the presence of much black blood in the royal family. In a stele from Napata, now in the Louvre, the mother, wife and sister of King Aspelut (about 825 B.C.) are represented as distinctly steatopygous, while the representations of Queen Amen-Tarit at Meroe some three centuries later are frankly Negroid. Moreover, even while a king exerted real authority at Meroe it would be entirely consonant with African politics and African customs for vassal 'kingdoms' to arise at the extremes of the state. So, when it is recorded on the authority of Eratosthenes, that in the third century B.C. the Sembritæ who occupied an island south of Meroe were ruled by a 'queen' but recognised the suzerainty of Meroe (**24**, Bk. xvii. chap. 1), we may think of the petty chieftains of the eighteenth century who were the true rulers of the country from Dongola to Sennar, though every sultan of Sennar claimed sovereign rights. There may have been many such 'states' ruled by women, just as at the present day in the Nuba hills the highest authority passes in the female line, and may be exerted by a woman.

Meroe seems to have been destroyed before the introduction of Christianity. Nevertheless, two if not three culture phases can be traced in its history. There was first a period of Egyptian influence under King Aspelut and his successors, then came an influx of Greek ideas, a phase which Professor Garstang would date from about the third century B.C. This is the period to which most of the monuments now visible belong, and it was succeeded by the period of Roman dominance. At Soba, on the Blue Nile a few miles above Khartum, Lepsius collected the cartouches of a number of kings and queens of Meroe; this site, the capital of the Christian kingdom of 'Alwah, was certainly inhabited through mediæval times, and may not have been fully deserted till three or four hundred years ago. No doubt northern influence diminished progressively, especially after the conquest of Egypt by the Arabs, when the rivalry between Christianity and Islam which culminated in the Crusades must have had the effect of closing Upper Nubia and the countries beyond to Mediterranean influence. Nevertheless, trade objects continued to come through, though there is nothing to show whether these travelled up the Nile or across the Eastern Desert from the thriving Mohammedan trading ports which, as Crowfoot has shown, were established there previous to the thirteenth century[5] (**4**, 542.)

[5] There is a particular form of bead made of chalcedonic agate, numerous examples of which have been dug up in the neighbourhood of Khartum. A large number of similar beads are said to have been found in Somersetshire a few years ago, but archæologists tell me that there is no sufficient warrant for their origin. But a chain of these beads found at Erding in Upper Bavaria and now in the Munich Museum (K. IV. 1924 in Room 2, Case 4) dates them, at least approximately, to the early mediæval period, Merovingian or earlier. Moreover, three large chevron beads of the usual type were said to have been removed from the body of an 'Arab' who fell at Omdurman, and I see no reason to doubt the truth of the statement. What I have said concerning the Ethiopia of Strabo closely follows the argument set forth by Crowfoot in *The Island of Meroe*, published by the Egypt Exploration Fund.

No doubt the territory over which the rulers of 'Alwah exerted authority extended south of their capital, yet beyond Soba, in the archæologically unexplored country south of the confluence of the two rivers, traces of northern influence quickly become fewer and less distinct. Nevertheless, at the present day among the hills between the White and Blue Niles the name Soba is still known, being recognised as that of a series of great queens who ruled over a mighty empire of the same name. I cannot say how wide the area may be over which this belief is held; my information was obtained at Jebel Gule fifty miles east of Renk. At the foot of the hills are two settlements of a people who call themselves Fung, but who are generally known as Hameg. These people say that the great Queen Soba whom they worship was their ancestress, but they also apply her name to certain stones which they regard as sacred. The most important of these is a spherical water-worn stone (about 18 inches in diameter) of a brownish colour, with large quartz veins traversing it in every direction. This stone was stated to have been the 'throne' of Queen Sheba, and is still the 'chair of kingdom' (*kursi memlaka*) upon which every Hameg paramount chief (*mangil*) assumes office. Besides this rock there are two others associated with Soba, and hence called Soba. Both are weathered boulders, partly embedded in the soil at the side of the track round the base of Jebel Gule. A prayer given me by a woman at one of these rocks ran somewhat as follows: 'Grandmother Soba . . . permit us to go on our journey and return in safety.' There was obviously the utmost confusion in this woman's mind between Soba the goddess and Soba the stone on which she had just placed a handful of sand. Soba may also be asked to relieve sickness, and is invoked during a dance held by the neighbours of a recently delivered woman, about the time when the young mother is allowed to leave her house for the first time. Few will doubt that in the Soba of the Hameg belief there is preserved the memory of such queens as Candace the ruler of the Sembritæ, grafted on the recollection of the great city, which to the Negroids of the Gezira no doubt appeared to dominate the north. Nor do these traces of ancient tradition stand alone; at Jebel Moya near the Blue Nile some 150 miles south of Khartum there is actual archæological evidence of northern influence. Here besides stone implements were found beads, and amulets, a number of scarabs, and small plaques bearing Ethiopian and Egyptian cartouches ranging from about 700 B.C. (**25**, 617), or perhaps going back to an even earlier date. I may also note that on the as yet unexplored site of Faragab in northern Kordofan, besides potsherds, stone implements and ivory objects I have found a carnelian bead identified by Professor Petrie as of XVIII. dynasty make, as well as dolomite and scolecite beads which are certainly not of Negro workmanship or character.

Faragab must have been an important site for a considerable period, and would well repay systematic examination; the mounds, which are some ten feet high, occupy a considerable area about a mile N.W. of the modern village. The potsherds found in them are of special interest, and among them are the remains of a type of pot which, as far as I can discover, is different from any in use in Africa at the present day. This type was oblong and rather shallow, decorated with geometrical patterns and produced at each end into a solid mass more or less covered with designs; its shape, in fact, was that of many Melanesian food bowls. Another interesting feature of the Faragab sherds is that many of the larger vessels were made on string mats (**21**). The large narrow-necked vessels found in such numbers in the necropolis at Meroe were made by this method, which is still in use for water vessels in northern Kordofan.

These sites seem to mark the southern limit of Egyptian influence as far as the actual transmission of objects derived from the north is concerned. Of the racial affinities of the inhabitants of Faragab nothing is known, but we are better informed concerning the old residents of Jebel Moya. The cemeteries of this site have yielded the remains of a tall coarsely built Negro or Negroid race with extraordinarily massive skulls and jaws (**5**). In a general way they appear to resemble the coarser type of Nuba living in South Kordofan at the present day, and it is significant that the cranial indices of the men of Jebel Moya and the Nuba hills agree closely. Thus there is the clearest

evidence that Egyptian influence reached south of Khartum, and since it has persisted to the present day in oral tradition among the tribes of the little known country between the Blue and White Niles, traces might equally be expected among the Nilotes of the White Nile. But strangely enough nothing of the sort has been found, although the Shilluk and Dinka are better known than any other of the Sudan tribes. On the other hand, the tribes of the Congo basin have a number of customs which do suggest Egyptian influence, and the same may be said perhaps of Uganda; so that it seems reasonable to believe that Egyptian influence spread up the White Nile and passed westwards across the Nile-Congo watershed. An alternate route would be along the Blue Nile and its tributaries the Dinder and the Rahad to the Abyssinian hills, southward through the highlands to about 5° N., and thence westward to the head waters of the Congo.

To return to the Shilluk and Dinka, the most northern of the Negro tribes of the White Nile. The fact that no cultural elements which can be connected with Egypt are found on the White Nile, where they might have been expected, suggests, either that the tribes now occupying the district were not there when Egyptian influence spread south, or that the country presented such difficulties that the foreign stream left it on one side, as would have been the case had it followed the route *via* the Blue Nile and the highlands of Abyssinia In other words, either the Shilluk and Dinka reached their present territory in comparatively recent times, or else led a wandering and precarious life in swamps as formidable as the Sudd of the present day. There is, I think, a good deal in favour of the latter view. The existence in the depths of the Sudd of Nuer communities, of which we know little except through rumour, shows that such a life is possible; while among the Dinka the Moin Tain or 'marshmen,' who possess no cattle and scarcely cultivate, but live by hunting and fishing, exist under almost as unfavourable conditions Moreover, there is abundant evidence that North-West Africa is drier now than it was a few thousand years ago, and if those authors are right who state that there was a general melting of glaciers in Europe some 5000 years B.C., giving rise to widespread floods (the origin of the Biblical deluge), the increased precipitation may well have given rise to a considerable northern extension of the Nile swamps. In support of this argument it may be noted, that in numerous XVIII. dynasty paintings Negroes are represented with bows and arrows and throwing sticks (boomerangs), *i.e.*, their weapons are not those of the northern Negroes of the present day, the Shilluk and Dinka, who are not bowmen and do not use the throwing stick Shilluk traditions state that they came from the south, and a language substantially identical with theirs is spoken by the Acholi of the Uganda Protectorate

Evidence pointing in the same direction exists on the physical side: the results of the archæological survey of Nubia show that even in late dynastic times the tall Negroids (E group) whose skeletons have been found near Shellal were mesaticephals (**2**, 80), with a cephalic index higher by three or four units than those of the Dinka and Shilluk respectively. On the other hand, a people with a cephalic index nearer that of the northern Nilotes had reached Nubia by the Byzantine-Pagan period (200-600 A.D.). Elliot Smith and Derry speak of these people (the X-group) as prognathous and flat-nosed Negroids who suddenly made their way north into Nubia (**2**, Bulletin V. 12) Sixteen X-group skulls (eleven male and five female) in the College of Surgeons give a cephalic index of 70·8, and comparing them with the series of about the same number of Dinka skulls in the collection, my impression is that as a group they show as many Negroid characters

It seems reasonable to believe that the Negroids, whose skeletons form the majority of those found in Negro graves in Nubia, belonged to the group of Negroes with whom the Egyptians were in contact on their southern frontier. In other words, the tribes resembling the modern Dinka were so little in effective contact with the Egyptians, that they did not reach Nubia till some 1500 years ago, the cattle-owning Negroes whose representations were so frequent being the tall mesaticephals whose remains occur in Nubia in late dynastic times.

The numerous records of Negro incursions from the Middle Kingdom

onwards suggest that the Negroes were driven north in a succession of waves by some force from which this direction offered the only chance of escape. Such can only have been applied by other Negroes behind them. It may well be that there was more or less continual ferment on the southern border of Egypt in the early part of the first millennium B.C., and that the northern Nilotes were beginning to make their reputation as fighting men. Indeed, the passage in Isaiah can scarcely bear any other meaning than that this people was working north with sufficient energy for their peculiarities and those of their land to have become known to the Mediterranean world. 'Ah, the land of the rustling of wings, which is beyond the rivers of Ethiopia: that sendeth ambassadors by the sea, even in vessels of papyrus upon the waters, saying, Go, ye swift messengers, to a nation tall and smooth, to a people terrible from their beginning onward; a nation that meteth out and treadeth down, whose land the rivers divide!' (Isa. xviii 1, 2, Revised Version) But while the tall Negroes seem to have been the first to reach Nubia in organised groups, stray examples of short brachycephalic Negroes (usually female) have been found as far back as protodynastic times. I am indebted to Professor Elliot Smith for the information that the four Negresses found in cemetery No. 79 at Gerf Hussein (2, Bull. iii. 22) were short in stature with relatively broad oval crania, while at Dabod in a Middle-Kingdom cemetery there was found a skeleton of a man measuring 1·61 m (about 5 feet 3 inches), with definite prognathism, typical Negro hair, and a cephalic index of 80 (2, ii. 121). Presumably these were representatives of the group of short mesaticephalic Negroes who are at the present time found on both sides of the Nile-Congo divide, but predominantly west of it, a group represented by the Bongo, Azande, and cognate tribes. We thus reach the position that the Nubians, who were proto-Egyptians, were, in the earlier part of their history, in contact with just that class of Negroes among whom customs and ideas apparently of Egyptian origin are found at the present day. It must not, however, be assumed that it was this contact that led to the dissemination of Egyptian ideas, indeed our present information suggests that it can scarcely have been sufficiently intense.

The following table, giving the measurements and indices available for the comparison of the E-group Negroids with the tall Negroes of the present day, shows that the former belonged to the mesaticephalic group, which includes the Burun, the Bari, and the Nuba. As regards head length, head breadth, cephalic index and stature, the E-group stands closer to the Nuba than to the other tribes, while even in head breadth it is as near the Nuba as the Dinka.

	H.L.	H.B.	C.I.	Stature
Shilluk	195	139	71·3	1,776
Dinka	194	141	72 7	1,786
E-group	190 [6]	143 [6]	75 68 [6]	1,723
Nuba	190	145	76·6	1,722
Burun	190	150	79·16	1,759
Bari	190	149	78	1,741

At the present day the mesaticephalic group includes the Hameg and the Berta of the hills between the White and Blue Niles. The excavations at Jebel Moya—also between these two rivers—have enabled Dr. Derry to show that in Ptolemaic times this hill stronghold was inhabited by tall mesaticephali with a cephalic index almost identical with that of the Nuba, so that we are led to conclude that all these tribes, including the E-group Negroids, belong to one and the same stock.

A number of similarities between Ancient Egypt and Modern Africa have been set out recently by Professor Petrie (15). He does not discuss the routes by which Egyptian influence may have reached Negroland, but simply marshals the evidence of similarity under sixty-one headings. A good many of these are

* The H.L. and H.B. of the E-group skulls have been increased by 7 mm. and 8·5 mm. respectively in order to make these measurements comparable with those on the living. For the same reason the C.I. has been increased by 2 units.

so widely spread outside Africa as to be of little evidential value; others, and this applies specially to material products, include such simple or obvious devices that they can scarcely be regarded as carrying weight; but there are a number of instances which are highly suggestive, and when to these are added yet other habits and customs common to Ancient Egypt and Negro Africa, a mass of evidence is presented which seems decisively indicative of Egyptian influence. This view does not imply that all the features common to Ancient Egypt and present-day Negroes are instances of borrowing; on the contrary, I hold that many common customs are but expressions of the wide diffusion of old Hamitic blood and ideas. To this ancient stratum I would attribute those customs which I have discussed in a previous paper (22), including burial by the Nilotes in the crouched position, the use of the throwing-stick (boomerang) by the Beja, and the killing of the divine king (or rainmaker).

The ideas and customs reported from tropical Africa which may be due to Egyptian influence may be classified provisionally in the following groups :

(i) Beliefs connected with the soul
(ii) Beliefs and customs connected with the king or the royal office.
(iii) Death customs.

(i) Beliefs concerning the soul. The Egyptians believed that each individual possessed several souls, the most important being (*a*) the *ka* or human double; (*b*) the *ba*, the bird soul which accompanied Ra in the sun barque through the other-world; (*c*) the *akh* or *khu* (fate unknown); (*d*) the *khaibet* or shadow; and (*e*) the *ab* or heart; that in one aspect at least this was something more than the physical heart is shown by the fact that after death the *ab* was weighed by Anubis in the presence of Osiris against the feather of truth. Numerous instances of 'multiple souls' resembling those of Egypt have been recorded from the Congo and West Africa; perhaps the most striking is afforded by the Bambala, who say that man is composed of four parts, the body *lo*, the double *ilo*, the soul *n'shanga*, and the shadow *lumelume*, while some have an additional element called *moena* (1, vol. ii. fasc. i. 124).

(ii) Beliefs and customs connected with the king or the royal office. The fact that the Pharaoh, the Shilluk king, the Dinka rainmaker, and many other African rulers were, or are, divine kings, who were at one time ceremonially killed and with whose bodily well-being the welfare of their kingdom was bound up, does not, to my mind, indicate borrowing, but points rather to a common origin, for I believe that the divine king is an old Hamitic institution, and that Hamitic blood or cultural influence has been active over a very great part of Negro Africa. On the other hand, there does seem a possible connection between the Egyptian Horus and the eagle totem of the Baganda king. In Egypt, once totemistic, the king was identified with the falcon, and was spoken of as Horus; the falcon was placed over one of his names, and on the great slate palette of Narmer, dating back to protodynastic times, the falcon (with one human arm) leading captive the north country obviously represents the king. Among the Baganda every king and prince, in addition to his clan totem, claimed the eagle totem, though no eagle clan existed [7] (18, 128).

(iii) Death customs. The majority of the customs which can probably be attributed to Egyptian influence are associated with death and burial; this is not surprising, considering how greatly the Egyptians were concerned with the after-life. Let us consider the main features of Egyptian burial in the following order: posture of the body in the grave, preparation of the body and coffin, form of the grave, offerings in and at the grave, worship at the grave. I have shown elsewhere that the custom of burying on the side in the embryonic position was widespread in Africa among peoples of Hamitic blood; but I do not regard this as due to Egyptian influence, but rather as part of a common Hamitic heritage.

In Egypt the body was prepared for the grave by an elaborate process of mummification; it was then enclosed in a coffin often of anthropoid shape. In tropical Africa numerous instances of attempts to preserve the body are recorded. In Uganda the body of the king was opened, the bowels removed, emptied,

[7] Dr. Allan Gardiner informs me that even in Egypt there are indications that the eagle and falcon were confused in Hellenistic times.

washed in beer, dried, and then replaced (**18**, 105), while among the Banyoro (**3**, 316) and the Makaraka (**9**, i. 297, ii. 361) other methods were adopted. It seems a far cry from the mummies of Egypt to the smoke-dried corpses of Equatoria, and it is not difficult to see that ancestor worship might easily give rise to attempts to preserve the body when everyday experience would suggest desiccation or smoking, but there are certain Congo tribes whose practices do suggest an actual link with Egypt. Among the Wambunda of Stanley Pool the body is placed in the squatting posture, the limbs are tightly flexed on the body and tied in that position, the whole being packed with a large quantity of spongy moss which is kept *in situ* by bandages. A gentle fire is kept up round the body for two or three months, after which it is rolled in native cloths and buried (**1**, fasc. ii. 176). The latter part of this ceremony hints that the attempts to preserve the corpse may have been imposed on an older habit of speedy burial; such an imposition could only have come from without.

Among the Wangata an important person of either sex is buried in a massive coffin with a lid carved to represent the deceased (**1**, i. fasc. ii. 180). It is difficult not to believe that here is an echo of the Egyptian mummy case. If this be so, may not the practice of a tribe near Lake Leopold II., who after a rough preparation of the body roll it in native cloth and place it in a canoe-shaped coffin (**1**, fasc. ii. 175), be regarded as connected with the funerary boats of Egyptian burial ceremony? Since the anthropoid coffin was unknown before the XI. dynasty, it follows that the northern influence must have been exerted after this period. Egypt's first great expansion (after the Pyramid builders) dates from the XII. dynasty, when Egyptian and Negro were in intimate contact at the Second Cataract, as shown by the celebrated decree of Senusert III. Further, about this time special importance seems to have been attributed to the funerary voyage on the Nile, indeed almost all the models of funerary boats in our collections are of this period.

If these facts be accepted as evidence of the date at which Egyptian ideas influenced Equatorial Africa, there are other customs which seem to indicate that this was not the only period of such cultural drift. The coffins of the III. and IV. dynasties were often large rectangular boxes designed and painted to represent houses. Now the Mayumbe roll the body of a dead chief in layers of cloth and place it in an enormous wooden coffin of rectangular shape, the top of which is carved to present a homestead (**1**, i. fasc. ii. 177). Again, the funeral ceremonial of the Ndolo seems reminiscent of this period. Immediately after death the Ndolo prepare the body, painting it red, touching up the eyebrows with charcoal, and propping it up with open eyes and mouth on a high seat in the very posture of the *ka* statues of the Pyramid-builders, *i.e.* seated with the forearms and hands upon the thighs, a position which I venture to say no Negro would adopt. The body remains here for a day, while more or less continual drumming and dancing goes on, and is then buried (**1**, i. fasc. ii. 176).

If I have not laid too much stress on the XII. dynasty *liaison*, it would seem that the cultural drift originating the Ndolo custom was earlier than that affecting the Wangata and the Mayumbe. Professor Elliot Smith tells me that in Egypt bodies were not deliberately painted red before the XXI. dynasty, but it is possible that the Ndolo confused the dead body with the effigy and—for the time of its exposure—treated it as the Egyptians treated their wooden statues from an early date onwards. Nor must it be forgotten that at the present day the Bari paint themselves red.

An Egyptian mastaba tomb consists of (i) a tomb chapel, which may or may not lead to a series of chambers. There may or may not be a *serdab*. The tomb chapel is distinguished by the false door which is placed on the west wall and faces east. Behind the false door is (ii) a pit. The burial may be at the bottom of the pit or (iii) in a recess at the side. The recess may lengthen out into a passage with (iv) a chamber at the end. The form of the tomb was to a very great extent the expression of the Egyptian belief that the soul, or souls, of the deceased visited the body in the tomb chamber, coming in and out by the shaft of the pit, and indeed the XVIII. dynasty papyrus of the priest Nebqed represents the human-headed *ba*-soul descending the shaft to visit the mummy (**18**, Pl. iv.). These beliefs also led to the burial of supernumerary stone heads to which the soul might attach itself should the body perish.

Recently eight life-size portrait heads of a princess and the courtiers of the court of Chephren have been found in the mastabas at Gizeh constituting the royal cemetery of the IV. dynasty (**17**, xiii.). The cartonnage busts, presumably of the deceased, represented as carried in funeral processions of the Middle Empire (*cf. e.g.*, Stele C 15 in the Louvre), are probably a development of the same idea. Similar expressions of belief occur in Negro Africa, the examples being too numerous and the resemblances too exact for this to be due to any other cause than actual borrowing.

I am indebted to Messrs. Torday and Joyce for the information that the Tofoke in the neighbourhood of the Stanley Falls make a grave which in principle and form comes extremely close to the ancient Egyptian. A circular pit is dug, about 6 feet in diameter and 8 feet in depth; about 2 feet from the floor is a horizontal passage, about 15 feet in length, and of sufficient size to allow the body to be pushed along it; at the end of the passage is a vertical shaft, not more than 1 foot in diameter, reaching to the surface of the ground. The grave is lined with mats, and the body is pushed into the horizontal passage; the main shaft is filled in, but the smaller shaft, being destined for the passage of the soul, is merely covered with branches and a little earth Over the grave a conical mound is erected, and on this a shed; here are put food and certain property of the deceased after the mound has been covered with charcoal A similar tomb, but without the special shaft for the soul and hence even more closely resembling the Egyptian mastaba grave, has been figured by Froebenius (**6**, Pl i) The body, apparently tightly covered with wrappings and with vessels for offerings near it, lay in a lateral chamber at the bottom of the pit. The mouth of the pit was covered by a mud dome, on the top of which there was a pot, the whole having a hut built over it A small aperture on the western side of the dome gave access to the shaft

In the Pyramids the parts of the mastaba tomb underwent special treatment; in the Meydum pyramid a sloping passage takes the place of the shaft, the passage probably being reminiscent of the sloping stairway of the proto dynastic mastaba The so-called 'trial passage' near the Great Pyramid, as well as the passages within it, seem reminiscent of a tomb with two sloping passages running in the same vertical plane and meeting at an obtuse angle This type, which may be called the double sloping passage tomb, is also found in Negro Africa, namely in Lower Senegal and Northern Hausaland, between 13° and 18° N. 'First . . passages were dug under the earth and, at their coincidence, the gallery was enlarged, as the first sketch of a building with an oval-shaped dome. This dome was panelled and strengthened with wood from the Borassus palm This domed underground vault contained the dead man and a good many things besides . . The Eastern hole was filled in, but the Western one was sealed with boards and only opened yearly to receive fresh offerings. A second and very strong dome, to which a covered passage gave access from the west, was raised on the surface exactly over the roof of the grave-chamber proper . . . and the mound was piled high over the whole . The entrance to the grave itself, which was opened but once a year for the insertion of the autumnal offering, was covered with planks laid horizontally But on all other occasions the priests held intercourse with the dead in the upper chamber' (**6**, i 25, 26).

Offerings made at the grave, and worship performed there, are so inextricably interwoven that they may be considered together It is probably true to say that every Negro tribe has ancestor worship in some form or another, and at some time makes offerings at the ancestral graves; but the following instance from New Calabar is so suggestive of ancient Egyptian influence, and mimics the supernumerary heads and cartonnage busts (already cited) so closely, that it does not seem necessary to give any other example. The *duen-fubara* is a carved and painted image representing the head and shoulders of the deceased. This is brought by night in solemn procession to the dead man's village a year after his death, and deposited for eight days in charge of someone of importance in the community. On the eighth day goats and fowls are sacrificed by the eldest son of the deceased before the *duen-fubara*, which is sprinkled with the blood. After a mimic battle in which the sons of the deceased are opposed by the men of the house in which the image was deposited, the latter yield, and the *duen-fubara* is carried in solemn procession

to the place prepared for it. Here it is placed 'in the hall or outer room of a house which has been specially built for the purpose and . . . the . . . house chapel—now consecrated by the spiritual presence, which has been previously invoked and conjured into this special emblem is daily swept and cleaned' (**10,** 162-164).

To sum up: concerning the early prehistory of the Anglo-Egyptian Sudan we have no more than indications. In the Neolithic stage, which appears to have persisted until a comparatively recent date, Negro influence, if not predominant over the whole area, was at least powerfully felt even in the north, as is shown by the distribution of polished axe-heads. But against this northward pressure must be set the continual extension of Egyptian culture, the evidence for which may best be found in the eschatological ideas and burial customs ('mummification' and anthropoid coffins) of the peoples of Equatoria. This influence, which seems to have persisted until mediæval times, may have reached tropical Negroland as early as the Middle or even the Old Kingdom. Nor was the Nile route the only one by which Egyptian influence was spread. Another and later drift extended westwards as shown by the coinage of the north African States, which enables us to fix its date within fairly precise limits. We do not know how far south this drift travelled, but it seems certain that it reached at least as far as the Senegal River and the great bend of the Niger.

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The following Papers were then read :—

1. *Fresh Light upon the Origin of the Semitic Alphabet.* By Alan H. Gardiner, *D.Litt.*[1]

Among the monuments discovered by Professor Petrie in Sinai (1905) were ten inscriptions in an entirely unknown writing. These appear to have a very important bearing upon the origin of the Semitic and kindred scripts.

That the date of these monuments is Pharaonic is beyond dispute. Professor Petrie is inclined to attribute them to the Eighteenth Dynasty, but there are indications, particularly the image of the god Ptah on one stele, that they may go back as far as the Twelfth Dynasty.

In character they are non-Egyptian, though closely imitating Egyptian work. There are two rough statues of the usual squatting type, and a sphinx which bears the Egyptian hieroglyphs for 'beloved of Hathor, lady of the Turquoise' besides the foreign characters. These three were found in the temple of Hathor at Serâbîṭ el-Khâdim, but the seven round-topped stelæ come from a mine about a mile and a half distant.

It is wholly impossible to interpret the inscriptions as any form of Egyptian writing, though many of the signs are identical with, and obviously modelled upon, the Egyptian hieroglyphs, *e.g.*, the ox's head, the human head, the human eye, the fish and the rope.

Only about one hundred and fifty signs can be distinguished, as the inscriptions are very much weathered, and among these it is impossible to make out more than thirty-two varieties at most. There is, in consequence, a very strong presumption that the new script is alphabetic.

Thus the newly-discovered inscriptions reveal to us a form of writing in all probability alphabetic, and certainly modelled upon the Egyptian hieroglyphic, existent on Semitic soil at a date not later than 1500 B.C. Without any closer investigation one might conjecture *a priori* that such a script must be related to the common parent of the Phœnician, Greek, and Sabæan alphabets. Does a more detailed analysis bear out this conjecture ?

A careful study of the available evidence bearing upon the nature of this common proto-Semitic parent shows (1) that very little confidence can be placed in the surviving forms of the Phœnician, Greek, and Sabæan letters, all of which have obviously been linearised in very different and highly individual ways; (2) on the other hand, the letter-names common to Greek and Phœnician show every appearance of a high antiquity; and (3) since in a few cases resemblances can be detected between the meanings of the names and the actual signs (cf. Phœnician  = 'alif, ἄλφα, an ox[-head], Phœnician  = *'ain*, an eye) it is reasonable to suppose that all the proto-Semitic letters were hieroglyphic, and represented the things signified by the letter-names, the values of the letters being taken from the names on what is known as the *acrophonic* principle.

But if the proto-Semitic alphabet was hieroglyphic, it must clearly have been borrowed from, or modelled upon, some other hieroglyphic system of writing. A derivation from the Cretan hieroglyphs or from the signs of the Phæstos disk has been advocated, but the old theory of Lenormant possessed an inherent plausibility greater than that of the more modern views: this French *savant* had made out a whole list of Egyptian hieroglyphs, to which, as he supposed, the Semites attached new values in order to create an alphabet of their own.

The new Sinai inscriptions go far to confirm Lenormant's hypothesis. There are three signs which are actually identical with those in his list, and there are a number of other signs which correspond ideally to the signification of the Semitic letter-names. Moreover, there is one group of four letters which recurs on five (or six) different monuments, and which can be interpreted without any difficulty as the word Ba'alat (house-sign = *bêth*, eye = *'ain*, crook resembling the ordinary Græco-Semitic form of *lamed* and a cross = *tau* 'mark'). Now, almost every Egyptian inscription from Serâbîṭ el-Khâdim names the goddess Hathor, and there could not possibly be a better Semitic equivalent for the name of this goddess than Ba'alat. Indirect confirmation may be gathered from the fact that the group of signs in question does not occur on the stele where Ptah is depicted.

[1] Published in full in *J. Egyptian Archaeology*, vol. iii. pt. 1, 1916.

The demonstration is, of course, incomplete; no other word can be detected, largely owing to the facts that the inscriptions are extremely badly preserved and that no word-divider is employed. Still, when the date and place of origin are borne in mind, it seems impossible not to believe that the new Sinai script is either the proto-Semitic script itself or else one of several very closely related tentative Semitic alphabets out of which the actual proto-Semitic alphabet was ultimately selected.

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2. *Cretan Analogies for the Origin of the Alphabet.* By Sir ARTHUR EVANS, *F.R.S.*

The great comparative value of the Cretan material in its bearing on the origin of the alphabet is that we have not only a complete syllabary of pictorial signs, but also, in many cases, their linear degenerations belonging to a later age. This analogy, as pointed out by me some years since, is decisive against theories of the origin of the Semitic alphabet, such as that of De Rougé, who derived it from certain hieratic Egyptian forms representing similar sounds, but having no reference to the actual meaning of the letter names.

So close is the analogy indeed that, as shown in a comparative table, both the pictorial form answering to the name of the Phœnician letter and a linearised version answering to its earliest known form constantly recur among the Cretan signs. To a certain extent the Minoan and Semitic characters appear to belong to related systems.

The fresh evidence adduced by Mr. Alan Gardiner purports to show that the Semitic letters were evolved from an indigenous pictorial or hieroglyphic source, and if the early forms go back before 1500 B.C. they cannot have been introduced from Crete, either directly or by Phœnician mediation, the non-Semitic character (also non-Egyptian) of about a third of the Phœnician letter names has still to be explained. But the present view, which resembles that proposed, though afterwards rejected, by Lenormant, that the Semitic letters were derived from certain early Egyptian hieroglyphs of which they were literal translations, is not borne out by Cretan analogy. Neither is it by that of early Babylonia. In both these cases the pictorial prototypes were indigenous. The later cuneiform system of Assyria represents a selection from earlier Babylonian characters that reveal their pictographic origin. It must also be observed that the old simple theory of Gesenius, according to which *Aleph* goes back to an early Semitic drawing of an ox, *Beth* of a house, and so forth, is easily worked out, and does not involve the complication of calling in Egyptian models. At the same time, in the Semitic, as in the Minoan case, we may well trace some formative suggestion from the Egyptian side.

3. *Discussion on the Influence of Ancient Egyptian Civilisation on the World's Culture.* (*a*) *Opening Statement by* Professor G. ELLIOT SMITH, *M.A.*, *M.D.*, *F.R.S.*[1]

This discussion is to be regarded as the logical extension of the argument on Megalithic Monuments and their Builders with which I opened a debate at the Dundee Meeting (British Association Report, for 1912, pp. 607-609), and the further communications on the 'Origin of the Dolmen' (1913) and 'The Origin and Spread of Certain Customs and Inventions'[2] (1914) which I have presented at the last two meetings of the Association.

[1] Published in full in *Bulletin John Rylands Library*, January 1916

[2] The themes of these two communications have been developed at length in 'The Evolution of the Rock-cut Tomb and the Dolmen,' Essays and Studies presented to William Ridgeway, Cambridge, 1913, p. 493; and 'The Significance of the Geographical Distribution of the Practice of Mummification: a Study of the Migrations of People and the Spread of certain Customs and Beliefs,' *Manchester Memoirs* (Literary and Philosophical Society), Vol. 59, 1915, the latter of which includes a critical study of the evidence and a considerable bibliography of the subject of the present discussion.

On these previous occasions I discussed the problems of the gradual diffusion of Egypt's influence to the neighbouring parts of Africa, Asia, and the Eastern Mediterranean Islands and Coasts, which began at a very early historical period. To-day I am calling attention to a mass of evidence which seems to prove that, towards the close of the period of the New Empire, or perhaps even a little later, a great many of the most distinctive practices of Egyptian civilisation suddenly appeared in more distant parts of the coastlines of Africa, Europe, and Asia, and also in course of time in Oceania and America; and to suggest that the Phœnicians must have been the chief agents in distributing this culture abroad.

The Mediterranean has been the scene of so many conflicts between rival cultures that it is a problem of enormous complexity and difficulty to decipher the story of Egyptian influence in its much-scored palimpsest.

For the purposes of my exposition it is easier to study its easterly spread, where among less cultured peoples it blazened its track and left a record less disturbed by subsequent developments than in the west. Mr. Perry, who is to follow me, will indicate, however, that once the easterly cultural migration has been studied the more complicated course of events in the west can be deciphered also.

The theses I propose to submit for consideration, then, are (*a*) that the essential elements of the ancient civilisations of India, Further Asia, the Malay Archipelago, Oceania, and America were brought in succession to each of these places by mariners, whose Oriental migrations (on an extensive scale) began as trading intercourse between the Eastern Mediterranean and India some time about 800 B.C., and continued for several centuries, (*b*) that the highly complex and artificial culture which they spread abroad was derived mainly from Egypt (not earlier than the XXIst Dynasty), but also included many important accretions and modifications from the Phœnician world around the Eastern Mediterranean, from East Africa (and the Soudan), Arabia and Babylonia; (*c*) that, in addition to providing the leaven which stimulated the development of the pre-Aryan civilisation of India, the cultural stream to Burma, Indonesia, the eastern littoral of Asia and Oceania was in turn modified by Indian influences; and, (*d*) that finally the stream, with many additions from Indonesia, Melanesia, and Polynesia, as well as from China and Japan, continued for many centuries to play upon the Pacific littoral of America, where it was responsible for planting the germs of the remarkable Pre-Columbian civilisation.

The reality of these migrations and this spread of culture is substantiated (and dated) by the remarkable collection of extraordinary practices and fantastic beliefs which these ancient mariners distributed along a well-defined route from the Eastern Mediterranean to America. They were responsible for stimulating the inhabitants of the coasts along a great part of their extensive itinerary (*a*) to adopt the practice of mummification, characterised by a variety of methods, but in every place with remarkable identities of technique and associated ritual, including the use of incense and libations, a funerary bier and boat, and certain peculiar views regarding the treatment of the head, the practice of remodelling the features and the use of statues, the possibility of bringing the dead to life, and the wanderings of the dead and its adventures in the underworld; (*b*) to build a great variety of megalithic monuments conforming to certain well-defined types, which present essentially identical features throughout a considerable extent, or even the whole, of the long itinerary, and in association with these monuments identical traditions, beliefs and customs; (*c*) to make idols, in connection with which were associated ideas concerning the possibility of human beings or animals living in stones, and of the petrifaction of men and women, the story of the deluge, of the divine origin of kings, who are generally the children of the sun or of the sky, and of the origin of the chosen people from incestuous unions; (*d*) to worship the sun, and to adopt in reference to this deity a complex and arbitrary symbolism, representing an incongruous grouping of a serpent in conjunction with the sun's disc, equipped with a hawk's wings, often associated also with serpent-worship, or in other cases the belief in a relationship with or descent from serpents; (*e*) to adopt the practices of circumcision, tattooing, massage, piercing and distending the ear-lobules, artificial deformation of the skull, and perhaps trephining, dental mutilations

and perforating the lips and nose; (*f*) to practise weaving linen, and in some cases also the use of Tyrian purple, pearls, precious stones and metals, and conch-shell trumpets, as well as the curious beliefs and superstitions attached to the latter; (*g*) to adopt certain definite metallurgical methods, as well as mining; (*h*) to use methods of intensive agriculture, associated with the use of terraced irrigation, the artificial terraces being retained with stone walls; (*i*) to adopt certain phallic ideas and practices; (*j*) to make use of the swastika symbol, and to adopt the idea that stone implements are thunder-teeth or thunderbolts, and the beliefs associated with this conception; (*k*) to use the boomerang; (*l*) to hold certain beliefs regarding 'the heavenly twins'; (*m*) to practice couvade and (*n*) to display a special aptitude for and skill and daring in maritime adventures, as well as to adopt a number of curiously arbitrary features in boat-building.

Many of the items in this list I owe to Mr. W. J. Perry, who in the course of this discussion will deal with other aspects of the problem, and especially the incentives that impelled these ancient mariners to undertake these remarkable adventures.

That this remarkable cargo of fantastic customs and beliefs was really spread abroad, and most of them at one and the same time, is shown by the fact that in places as far apart as the Mediterranean and Peru, as well as in many intermediate localities, these cultural ingredients are linked together in an arbitrary and highly artificial manner to form a complex structure, which it is utterly impossible to conceive as having been built up independently in different places.

The fact that some of the practices which were thus spread abroad were not invented in Egypt and Phœnicia until the eighth century B.C. makes this the earliest possible date for the commencement of the great wandering which distributed the whole culture-complex, though certain of its constituent elements were diffused abroad to neighbouring lands long before then.

(*b*) *On the Influence of Egyptian Civilisation upon the World's Culture.* By W. J. Perry, B.A.[3]

If on Fergusson's 'dolmen' map for Spain, Portugal, and France[4] be plotted out the distribution of ancient pre-Roman and pre-Græcian mines mentioned by Professor Gowland,[5] it will be found that the area occupied by the two are identical. In Northern Africa megalithic structures are found in that region comprising Tunis and Algiers which contains mineral wealth, and where ancient mine-workings are recorded; also the stone ruins and terraces of Rhodesia and the country to the south are associated with ancient mine-workings. Those parts of India which show signs of megalithic influence, as, for example, Southern India, with Ceylon, Chota Nagpur, Assam, and the sub-Himalayan States, and also Thibet, are those parts which contain much mineral wealth in the form of gold and precious stones of various kinds. Assam, Tibet, Chota Nagpur, and Southern India were gold producing regions in ancient times; the States of Kullu, Garhwal, Nepal, Bhutan, and Sikkim, as well as Southern India and Rajputana, formerly produced much copper.

The distribution of the pearl oyster in the Indian and Pacific Oceans, as well as the Gulf of Mexico, closely defines the area of megalithic influence. The exceptions are West Australia, where pearls are found in abundance, their presence being unaccompanied by any signs of megalithic influence; and Peru, where ample signs of megalithic influence are present without pearls. But in South America the area of megalithic influence agrees well with that of metals and precious stones. The distribution of amber and metals in the Baltic region seems to agree closely with that of megalithic structures.

The pile-dwelling region of Switzerland and Upper Austria, as well as the

[3] Published in full in Memoirs and Proceedings of the Manchester Literary and Philosophical Soc., vol. 60, pt. 1, 1915; pp. 1-36.

[4] *Rude Stone Monuments.*

[5] Huxley Memorial Lecture, *Jour. Roy. Anth. Inst.* 1912, *Archæologia*, 56.

Terra-mare settlements of Italy, are closely allied in culture, and undoubted traces of Egyptian influence are present in the earliest settlements of these regions. The distribution of the pile-dwellings of Switzerland and Austria agrees well with that of ancient mine-workings mentioned by Professor Gowland. The Terra-mare settlements are all situated in the basin of the Po, the one region in Italy where gold was washed extensively in ancient times. But not only is a general agreement found between the distributions of megalithic influence and ancient mine-workings, but the technique of mining, smelting, and refining operations is identical in all places where the earliest remains have been found. Professor Gowland has shown that Britain, Spain, Switzerland, Egypt, and Japan, as well as other places, were once the seats of metal industries. The form of the furnaces used; the introduction of the blast over the mouth of the furnace; the process of refining whereby the metal is first roughly smelted in an open furnace and afterwards refined in crucibles; as well as the forms of the crucibles and the substance of which they were made, are the same in all places where traces of ancient smelting operations have been discovered. This last group of facts serves to strengthen the conclusion derived from the consideration of distributions; it also serves to identify the cultural influence which was at work in the early neolithic settlements of Switzerland and elsewhere with the megalithic influence.

The conclusion to which all these facts point is that the search for certain forms of material wealth led the carriers of the megalithic culture to those places where the things which they desired were to be found. The presence or absence of the desired form of wealth seems to determine the presence or absence of megalithic influence.

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4. *Egyptian Jewellery.*

By Professor W. M. Flinders Petrie, *D.C.L., LL.D., F.R.S.*

The XIIth Dynasty is recognised as the great period of jewellery in Egypt. This has been emphasised by the jewellery of a princess found by the British School at Lahun, which is in some respects finer than any yet known. The group belonged to different reigns; that of Senusert III., the father of the princess, and that of Amenemhat III. under whom she lived. The most important objects were a pectoral of each reign, with hawks as supporters of the cartouche; a crown of gold, with rosettes around, and long plumes and streamers of gold; a silver mirror with hawk of gold and obsidian; besides which were bracelets, necklaces, and vases of the known forms. All of the framing is of gold, and the inlays and beads are of turquoise, lazuli, carnelian, and amazonite. The workmanship and detail are of the most minute and perfect quality.

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5. *Notes on the Neolithic Egyptians and the Ethiopians.*[1]

By Professor V. Giuffrida-Ruggeri.

Up till the end of the III. Dynasty the people of Egypt present similarities which justify us in regarding the tribe which manufactured and used copper tools as a wave of Ethiopians comparable with the earlier Neolithic peoples, or possibly as the same people after they had obtained copper from Sinai. But in the IV., V., and VI. Dynasties as shown in the Giza series in Lower Egypt, or later in Upper Egypt, differences appear with mummification and the era of the Pyramid builders which point to the conclusion that while the prehistoric series were largely made up of Ethiopians, in the later period a great infiltration set in, proceeding in an opposite direction, from Syria, Sinai, and the North Arabian coast, territory already occupied by the Mediterranean Race. A monument attributed to the I. Dynasty represents the triumph over the Anu which became a traditional fête, the Anu being shown as a kneeling African captive. The Egyptians of the historic epoch called their predecessors 'Anu,'

[1] To be published in full in *Man*.

of whom the Anu-Seti were the inhabitants of Nubia living on the Nile, Seti being the traditional representative of Upper Egypt. The defeat of this people may represent the moment of the change in Upper Egypt. As a result there took place a cross between two elementary species, the Ethiopians, belonging to an elementary species of equatorial origin, and the Egyptians, belonging to an elementary species of Nordic origin.

THURSDAY, SEPTEMBER 9.

The following Papers were read :—

1 *A Communication from Professor E. Manouvrier entitled 'Une Application Anthropologique à l'Art Militaire.' By* Professor ARTHUR KEITH, *M.D., F.R.S.*[1]

In his Presidential Address to the Anthropological Section at Birmingham (1913) Sir Richard Temple emphasised the value of a knowledge of anthropology for those who are called to occupy administrative posts in the British Empire. In recent years Professor Manouvrier, Secretary of the Anthropological Society of Paris, has sought to apply certain principles of physical anthropology to the training of soldiers. At Professor Manouvrier's request a *résumé* is given of 'Une Application Anthropologique à l'Art Militaire : Le Classement des Hommes et la Marche dans l'Infanterie'—a publication issued in 1905, but which has passed without notice in this country. Professor Manouvrier maintains that, on the march, soldiers should be grouped according to length of lower extremity rather than according to stature. It is maintained that physical fatigue is much less in companies arranged on the principles proposed by Professor Manouvrier than in those where the customary arrangement is adopted.

2. *Hereditary Syndactilism and Polydactilism (with Skiagraph Exhibit). By* Dr. J. MANSON.

3. *Photographic Models of Egyptian Tombs. By* ROBERT MOND.

4. *The Greek Element in Asia Minor. By* R. M. DAWKINS, *M.A.*

The Greek element in Asia Minor has existed under the domination of the Turks ever since the arrival first of the Seljouks and then of the Ottomans. It was, however, not annihilated by the conquerors, and the regions where it survived in greatest numbers are marked also by the preservation of the Greek language. Thus, although in general the Greek Christians in Asia Minor talk Turkish, and whatever Greek is used is due to the influence of the schools, in some parts of Cappadocia and Pontus Greek is still the vernacular of the Christian population. In the western parts of Asia the destruction of the Greeks was more complete, and therefore there the language has only survived in a few scattered villages. This local Greek is of great importance from many points of view. Its mixture with Turkish is of great linguistic interest; many features in its grammar make it plain that it rests upon a form of Hellenistic Greek different from that which has produced the ordinary modern Greek, and

[1] Published in full in *Army and Navy Gazette*, October 16, 1915; pp. 90 *seq.*

it is therefore of use in reconstructing the features of the Hellenistic language; and lastly its vocabulary reflects in a remarkable way the history of the country. Thus the Italian loanwords which are so common in ordinary Greek are very rare in Asia, but there is no lack of Latin words. The reason for this is that between the late Roman and early Byzantine period, when the Latin words were taken into Greek, and the period following the Fourth Crusade, which gave the Italian words to the language, there occurred the first irruptions of the Turks, which separated the Greeks of Asia from their European brethren, and their language was in this way shielded from the influence of Italian. In the same way, of the Slavonic words found in Modern Greek very few are in use in Asia; the only considerable Slavonic element is formed by the Russian words which modern conditions are bringing into the dialect of Pontus. In Cappadocia there is also an Armenian element in the vocabulary. The condition of these Greek communities has grown sensibly worse since the New Turk *régime*; in particular the introduction of conscription is causing wholesale emigration, especially from Pontus into Russia. It seems, too, that the aim of the Turks is now the total destruction of the Greek population, and the outlook is dark indeed. It would indeed be terrible if the time which has seen the increase of the territory of free Greece were also to see the end of those survivors of the old Byzantine rule in Asia Minor.

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5. *Joint Discussion with Section E on Racial Distribution in the Balkans.* (*a*) *Opening Statement by* Professor G. Elliot Smith, *M.A., M.D., F.R.S.*

No adequate settlement is possible of the problems with which statesmanship will soon have to deal in the Balkans, especially when it is recalled that the present struggle is for the due recognition of the claims of race and nationality, unless the facts of geography and racial distribution are taken into consideration. But I want to make it perfectly clear at the outset that a multitude of other factors (with which we are not concerned in this discussion), historical, political, economic, and religious, must determine the application of the facts of ethnology if any stable agreement is to be arrived at; and even so, that the primary element in the establishment of a real peace is the acquisition on the part of the peoples concerned of the art of tolerance and the spirit of compromise in attempting to realise their legitimate national aspirations.

The geographical situation of the Balkans its peculiarly distinctive relations to Europe, Asia, and to the Adriatic, Ægean, and Black Seas—marked it out even in prehistoric times as a place of ethnic confusion, exposed on three sides to maritime people, not only of Mediterranean, but also of Armenoid stock; on the north quite open to incursions of all kinds of people from Europe and Asia; and as the threshold of Europe the natural meeting-place of Europeans and Asiatics passing respectively to and from Anatolia The configuration of the country favoured segregation of groups of people and helped towards disunion. These factors have influenced its history and disturbed its peace for fifty centuries. Interposed between Rome and Byzantium it was in turn subject to each, and the scene of strife between warring empires and religions It has been exposed to a long succession of raids and immigrations from Goths, Huns and other Ugrian and Turki people, and Slavs; and when various settlements of these peoples took possession of a large part of the peninsula and amalgamated with their predecessors to form the two great Slavonic nations—Southern Slavs and Bulgarians—the intrusion of the Turks foisted upon the Balkans a new oppression and another religion to add to its unrest. Since then the rivalry between Hungary (with the Teutonic Powers) and Russia has played havoc with the Balkan powers. A minor difficulty has been added by the problems of the Jews.

The elimination of Turkish influence from the Balkans, where neither the amount of Osmanli blood nor administrative achievement justifies its retention, reminds us that the Turk is not responsible for the amazing tangle there; he was merely an aggravation of an already involved situation, to the complexities

of which his race, religion, and methods of government added a potent element of confusion. His approaching departure will still leave the most difficult problems unsolved.

[The astounding complexities of the distribution of races and religions were then expounded—somewhat on the lines of Professor Jovan Cvijic's memoir, 'Die ethnographische Abgrenzung der Volker auf der Balkanhalbinsel,' *Petermanns Mitteilungen*, 59. Jahrg., 1913, p. 113.]

In spite of all the conflicting interests created by different religions and histories, ethnological considerations, no less than geographical and economic circumstances, clearly and definitely link together the Slovenes, Croats, and Serbs as one people united by a common origin and literary traditions; and as a race whose domain includes not only the whole of Croatia (with Slavonia), Bosnia, Herzegovina, Montenegro, and most of Serbia, as at present delimited, but also Dalmatia, nine-tenths (all except Trieste and its neighbourhood) of Istria, Carniola, and a strip of Southern Hungary. This is the territory of the Southern Slav nation.

On ethnological grounds Bulgaria has a greater right than Serbia to the part of Macedonia now in occupation by the latter (and her geographical position in the centre of the Balkans, with no other outlet for expansion such as the other nations aspire to, serves to emphasise her claims in this respect); and as regards the Dobrudja, with its confused jumble of races, Bulgaria's claim to its possession is clearly more justifiable on racial grounds than that of its present occupant, Roumania.

The latter is not a Balkan Power, either geographically or ethnologically. Yet for historical reasons it cannot entirely be dissociated from the discussion of the other peoples. Beyond the boundaries of Roumania, the population of parts of Russia (Bessarabia), Austria (the Southern Bukovina) and Hungary (Transylvania), and the north-east corner of Serbia is mainly Roumanian.

It would make the discussion far too diffuse if we were to deal with the question of Albania: the distinctive ethnic and historical features of the Albanians and the racial problem in Greece and the distribution of the Hellenes. These matters can be considered only in so far as they affect the problems of the Southern Slavs.

(*b*) *Diagrammatic Map illustrating the Ethnic Relations between the Adriatic, Drave, and Danube.* By Sir Arthur Evans, *F.R.S.*

This map was prepared on the basis of observations carried out by the author in the course of many years' travel in every part of the area. The great extent of the country was occupied by a mass of South Slav population or Jugoslavs. The two South-Eastern members, Croats and Serbs, besides the countries named after them, occupy Dalmatia, Bosnia, Herzegovina, and Montenegro. They speak the Serb language. The Slovenes to the N.W. of them speak a closely allied dialect and regard themselves as part of an indivisible Jugoslav mass. They extend into Carinthia to the country surrounding Villach and Klagenfurt and into Styria to the neighbourhood of Gratz. The Western part of the Banat of Hungary is predominantly Serb, with islands of Germans, Magyars, and Roumans.

The Italian element preponderates in the lower part of the Izonzo valley at Trieste, Pola, and Western Coast of Istria, to which may be added the isle of Lussin. In Dalmatia it preponderates in the town (but not the district) of Zara, but elsewhere, according to the latest returns, is only about three per cent. of the population. The social and commercial use of Italian and impress of Italian culture gives foreigners a wrong impression. Dalmatia is the centre of the Jugoslav national movement.

It was pointed out that the formation of a Jugoslav State occupying the area to the Drave and Mur had a very important bearing on the future relations of Britain, France, and Northern Italy with Constantinople and the Near East. Only a few railway links had to be completed to reopen what was the highway between the East and West under the Roman Empire. The

railway route from the Simplon and Milan *via* Gradisca and a link to be constructed to Ljubljan (Laibach) would follow almost exactly this main Roman road-line, the *cursus publicus*—by the easiest pass over the Julians, down the Save valley, and thence by Belgrade and Nish. It is approximately marked by a series of Imperial cities, from Aquileja to Siscia, Sirmium, and Naissus (Nish)—the modern representatives of which should rise to new prosperity. The important point is that the establishment of this united South Slav State would restore to its natural channel main lines of intercourse at present diverted by German and Magyar interests to a long detour *via* Vienna and Budapest. It would place our connexions with the East in friendly hands.

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6. *Some Offerings to the Venetic Goddess Rehtia.*

By Professor R. S. Conway, *Litt.D.*[1]

In the last thirty years two types of votive offerings have been found, among others, on the site of the temple of this goddess, whose name meant *straightness*, at Este, the modern town on the site of the ancient Ateste, about fifteen miles south of Padua. The language of the inscriptions is of peculiar importance in comparative philology, as it is structurally intermediate to Greek and Latin. The tribe of the Veneti are not less interesting from the standpoint of the archæologist, because the remains show that they had lived undisturbed from the beginning of the Early Iron Age down to the invasions of North Italy by the Gauls in the fifth and subsequent centuries B.C. The earliest Venetic inscription yet known is on a vase which Sir Arthur Evans has referred with confidence to the sixth century B.C.

The two groups of offerings came from the end of the Venetic period proper, *i.e.* from the period in which the Venetic language was beginning to be superseded by Latin, a period somewhere within the last two centuries B.C., probably between 200 and 100 B.C. The process was probably fairly rapid after the foundation of the Latin colony of Aquileia in 183 B.C., on a site just west of the root of the Istrian peninsula near the mouth of the Sontius, the modern *Isonzo*; it had began about forty years sooner with the planting of Placentia and Cremona in 218 B.C., and notably furthered by the planting of the colony of Bononia in 190 B.C. The first datable Latin inscription of the district is a boundary stone of 141 B.C.,[2] by which time the process was probably not far from complete. The first group consists of what has been probably explained as Votive Nails and Wedges, representing the action of the goddess in the same way as a thunderbolt represented that of Jupiter, or clubs Hercules, or a trident Poseidon. Horace (*Odes* i. 35, 18) describes the Etruscan goddess of Fate, *Nortia*, as carrying *clavos trabales et cuneos manu aena*, and these objects seem to suggest that the Venetic goddess had some kinship with the Etruscan deity, using nails and wedges to build up and pull down at her will. About eighteen or nineteen of the specimens were explicitly dedicated to *Rehtia*, but far the largest number (some 186 out of about 210) have no articulate inscriptions, but either single alphabetic signs repeated along their sides or linear ornament with no signs at all. An intermediate group show mock-inscriptions, *i.e.*, confused combinations of letters from the Venetic alphabet which make no words at all, and which include many badly formed letters. In the alphabetic class far the commonest letter is  (which in Venetic alphabet denotes *t*), next to that  and  (*e*, *v* and *z*), are most common,  (*k*) rarer, and  (*o*),  (*n*), and  (*a*), very rare. The rectilinear character of all the signs seems connected with the goddess's name and functions.

The second group of objects is one of great value to students of Venetic as they give us a perfectly certain guide to the transcription of the Venetic

[1] To be published in full in *Journ. R. Anthrop. Inst.*

[2] *C.I.L.* v. 2491 *inter Atestinos Patavinosque.*

alphabet, which they contain fully written out, with the letters given first singly and then in certain combinations (*e.g., tr, tn, tl, pr, pn, pl*). The history of the alphabet is as yet by no means fully made out, but the absence of signs for *b*, *d*, and *g*, the compound symbol *vh* for *f*, and the placing of the symbol for *o* at the end of the list, make it practically certain that it reached the Venetic through Etruscan channels.

These alphabetic bronze tablets have many curious features. They measure, roughly speaking, about 8 in. by 5 in., and they are divided into horizontal bands, generally ten or eleven, by straight lines along the length of the tablet, the first, or lowest, five of which are of a fixed character. The first contains the fifteen consonantal signs of the alphabet, followed by one vowel (*e* in two examples, *ii* in another, *o* in a fourth); the next four lines each contains, sixteen times, a single letter, *a* sixteen times in l. 2, *k* in l. 3, *e* in l. 4, and *o* in l. 5.

The nature of these tablets is unknown. Guesses were that they were schoolmasters' offerings; that they had some magical value—but what? I am inclined to ask whether any nearer parallel to them could be found than the boards used by Greeks and Romans for playing a game of luck and skill combined like our backgammon, called in Latin *duodecim scripta*, from the twelve lines on each side of the board which marked it out; unfortunately no specimens seem to have survived. If so, they would be dedications either by professional players or by lucky winners.

7. *Excavations on the Roman Site of Uriconium (Wroxeter).* *By* J. P. Bushe-Fox.

FRIDAY, SEPTEMBER 10.

The following Papers were read :—

1. *Ceremonial and Descent in Ambrim.* *By* Dr. W. H. R. Rivers, *M.A., F.R.S.*[1]

The ceremonies of the island of Ambrim in the New Hebrides fall into two groups, those known to have been introduced from elsewhere and those believed to be indigenous.

The most important of the introduced ceremonies belong to a complex institution called the 'Mangge,' which resembles in its main characters the 'Sukwe' of the Banks Islands.[2] One of the chief features of the ritual of the higher grades is the manufacture of an image in human form in which it is believed that the ghost of the father's father comes to reside and to look after the welfare of his descendant. Neither in this nor in any other of the introduced ceremonies is any part taken by the mother's brother or the mother's people.

In several of the indigenous ceremonies, on the other hand, a leading part is taken by the mother's brother and other people of the mother's village. Thus, in the ceremonial accompanying incision the mother's brother holds a boy during the operation and dresses his wound. Afterwards the boy visits his mother's village and numerous gifts of pigs and food pass between the village of the boy and that of his mother.

In another ceremony called 'Wor' a heap of stones is made for a man by his mother's brother, and transactions in pigs and other objects of value take

[1] To be published in full in *Journ. R. Anthrop. Inst.*

[2] Rivers, *History of Melanesian Society*, Cambridge, 1914, i. 61.

place between the village of the man for whom the 'Wor' is made and that of his mother. The ceremony is actuated by the belief that after death a man goes to his mother's father. The same idea underlies another ceremony called 'Pâripârpâr,'[3] in which an image is made for a man by his mother's brother. It is believed that the pigs killed on this occasion go to the maternal grandfather of the man for whom the image is made and clear the track by which he will pass when he dies.

The mother's brother also takes the leading part in an indigenous ceremony called 'Lengfa,' in which women buy the right to wear certain ornaments.

At the present time the institutions of Ambrim are patrilineal. A man belongs to his father's village, and in so far as individual property exists in this island it is inherited by the children, while the social group which holds most of the property in common is one which has in the main a patrilineal character. The close relation with the mother's brother and the mother's people in the indigenous ceremonies has no meaning in a patrilineal society, but would be the natural accompaniment of ancient matrilineal conditions surviving in ceremonial.

The ritual of death provides further evidence in this direction. The rites following the death of a man are almost an exact replica of those performed when he took his last step in the 'Mangge,' but with additional features in which the village of the mother of the dead man is concerned. The introduction of the 'Mangge' and the incorporation of its ceremonial in the ritual of death has not succeeded in abolishing those features of this ritual which show the social relations of the dead man with his mother's village. Ambrim adjoins a region characterised by matrilineal institutions. The fact that its older stratum of ceremonial brings a man into relations with his mother's people affords the most decisive proof that in this part of Melanesia the matrilineal institutions are the older and the patrilineal the more recent.

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2. *Royal Marriages and Matrilineal Descent.*[1] *By* Miss Margaret A. Murray.

At certain periods in the history of every nation inheritance was in the female line. In royal families this custom appears to have continued to a later date than among the mass of the people. In these cases the man who married the queen becomes king, and marriages within the modern degrees of affinity were common. Such marriages, when recorded by contemporary chroniclers, are not regarded as unusual, *e.g.*, in Egypt in the XVIIIth dynasty and the early kings of Judah. But when such consanguineous marriages are recorded by foreign observers or later historians, as among the Ptolemies and the early Roman emperors, they are ascribed to vicious propensities instead of to the stern political necessity to which they are really due, and which the non-contemporary or foreign historian failed to understand.

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3. *The System of Kinship among Primitive Races in connection with their mode of grouping.* *By* Mlle. Nadine Ivanitzky, *Attachée scientifique à l'Institut Solvay à Bruxelles.*

(*a*) All manifestations of the social life of primitive races being in strict correlation with the concrete necessities of life, the elements of their social organisation are with difficulty separated from each other. This brings it about that, when we study one special aspect of their life, we must always return to the social complex which supports this special aspect.

[3] The sound for which I use the sign *â* does not differ greatly from *â*, and might easily be confused with it.

[1] To be published in *Man*.

Thus it is, for example, that the question of kinship leads us to consider the special social arrangements which regulate the organisation of subsistence.

(*b*) The mode of life in little groups of kinsmen is enforced upon them by the conditions of their environment: (1) their rudimentary technical knowledge and implements, which render the resources of a district very limited and do not permit of the support of a large number of persons; (2) the existence of other groupings which seek their subsistence by the same means and render impossible their spreading indefinitely.

(*c*) The social unity of the grouping, ensured by the order, rigorously defined, in which the rights of an individual are transmitted from one generation to another.

(*d*) The necessity for adult members of a little grouping to seek their wives from neighbouring settlements, and the exodus of women from one group to another which is the result of that necessity.

The difference which, consequently, the native establishes between two categories of his relatives, those who belong to the grouping into which he was born, and those who are strangers to this grouping, and, as a result of this, the difference in terms which designate the relatives on each side.

(*e*) The grouping keeping together by the fact of being born one from the other, an individual transmits to another only the rights which he has *conjointly* with other members of the group.

The genetic relationship which unites him to his own children has no importance, seeing that his brothers and the children of his brothers, in consequence of their being born in the same grouping, have exactly the same rights. From this arises a seeming paradox, which consists in the fact that the native confounds under the same appellation relationships which are essentially different in our estimation.

(*f*) The mode of transmission of the rights of enjoyment of the soil in the groupings which are cemented by maternal descent.

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4. *Early Man in East Anglia* *By* Rev. H. J. Dukinfield Astley.

It is unnecessary to enlarge on the classification now accomplished of Palæolithic times, chiefly from the data in the French caves. Formerly it was sufficient to differentiate the Drift and the Cave periods.[1]

It is now realised that the Cave Period was of vast duration and consisted of a succession of well-defined epochs, as did also the Drift.

Various classifications have been attempted as knowledge has improved—those of Mortillet, Piette, Hoernes; the latest are those of M. Rutot and the Abbé Breuil, and a careful table in the Report of the last Prehistoric Congress at Geneva, 1912.

This definitely established the existence of the Aurignacian Period between the Mousterian and Solutrian periods, tentatively suggested by the Abbé Breuil at the Monaco Congress in 1906. (The names are derived from the caves containing the characteristic culture.)

As regards England, Professor Sollas has assigned the Paviland Cave to the Aurignacian Period, and some implements with distinctive Aurignac features have been found in Kent's Cavern and Wookey Hole.

The object of this communication is to show reason for affirming the habitat of Aurignac Man in districts where no caves exist. The 'Cissbury' type shows unmistakeable Aurignac affinities.

A rich field has been lately disclosed in East Anglia—not only in the Palæolithic Floors at Thetford Warren and Lakenheath and Icklingham, so untiringly explored by Dr. Sturge, but in the now celebrated 'Grime's Graves' near Brandon.[2]

Mr. Reginald Smith's doubts have led to further excavations undertaken in 1914. The results are now before the public. These show implements of

[1] Evans, *Stone Implements*, and Avebury, *Prehistoric Times*.

[2] *Description of Grime's Graves, Canon Greenwell's excavations*, 1870—all assigned to the Neolithic Age.

undoubted Mousterian and Aurignac types, and go to prove that the original miners belonged, not to the Neolithic people, who came here when Britain was already an island, but to the Cave people, who arrived here immediately preceding the Wurm glaciation, and continued after it passed away, while the British Isles still formed part of the Continent.

It is suggested that the sand covering the pits is Loess.

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5. *Chest Types in Man in relation to Disease.*

By Dr. G. W. Hambleton.

SECTION I.—PHYSIOLOGY.

PRESIDENT OF THE SECTION: PROFESSOR W. M. BAYLISS, M.A., D.Sc., F.R.S.

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address :—

The Physiological Importance of Phase Boundaries.

EVEN a hasty consideration of the arrangements present in living cells is sufficient to bring conviction that the physical and chemical systems concerned operate under conditions very different from those of reactions taking place between substances in true solution. We become aware of the fact that there are numerous constituents of the cell which do not mix with one another. In other words, the cell system is one of many 'phases,' to use the expression introduced by Willard Gibbs.

Further, parts of this system which appear homogeneous under the ordinary microscope are shown by the ultra-microscope to be themselves heterogeneous. These are in what is known as the colloidal state. Some dispute has taken place as to whether this state is properly to be called a heterogeneous one, but it is sufficient for our purpose to note that investigation shows that the interfaces of contact between the components of such systems are the seat of the various forms of energy which we meet with in the case of systems obviously consisting of phases which can be separated mechanically, so that considerations applying to coarsely heterogeneous systems apply also to colloidal systems. Although the phases of a colloidal system cannot be so obviously and easily separated as those of an ordinary heterogeneous one, this can be done almost completely by filtration through membranes such as the gelatin in Martin's process. To avoid confusion, however, it has been suggested that the colloidal state should be spoken of as 'micro-heterogeneous.' There are, in fact, certain phenomena more or less peculiar to the colloidal state and due to the influence of the sharp curvature of the surfaces of the minutely subdivided phase. The effect of this curvature is a considerable pressure in the interior of the phase, owing to the surface tension, and it adds further complexity to the properties manifested by it.

We see, then, that the chemical reactions of chief importance to us as physiologists are those known as 'heterogeneous.' This class of reactions, until comparatively recent times, has been somewhat neglected by the pure chemist.

In some of its aspects, the problem before us was discussed by one of my predecessors, Professor Hopkins, as also by Professor Macallum, but its importance will, I think, warrant my asking your indulgence for a further brief discussion. Permit me first to apologise for what may seem to some of those present to be an unnecessarily elementary treatment of certain points.

It is easy to realise that the molecules which are situated at the interface where two phases are in contact are subject to forces differing from those to which the molecules in the interior of either phase are subject. Consider one phase only, the molecules at its surface are exposed on the one side to the

influence of similar molecules; on the other side, they are exposed to the influence of molecules of a nature chemically unlike their own or in a different physical state of aggregation. The result of such asymmetric forces is that the phase boundary is the seat of various forms of energy not present in the interior of the phase. The most obvious of these is the surface energy due to the state of tension existing where a liquid or a gas forms one of the phases. It would lead us too far to discuss the mode of origin of this surface tension, except to call to mind that it is due to the attractive force of the molecules for one another, a force which is left partially unbalanced at the surface, so that the molecules here are pulled inwards. The tension is, of course, only the intensity factor of the surface energy, the capacity factor being the area of the surface. We see at once that any influence which alters the area of the surface alters also the magnitude of that form of energy of which we are speaking.

This is not the only way in which the properties of substances are changed at phase boundaries. The compressibility of a solvent, such as water, are altered, so that the solubilities of various substances in it are not the same as in the interior of the liquid phase. It is stated by J. J. Thomson that potassium sulphate is 60 per cent. more soluble in the surface film. The ways in which the properties of a solvent are changed are sometimes spoken of as 'lyotropic,' and they play an important part in the behaviour of colloids. We meet also with the presence of electrical charges, of positive or negative sign. These are due, as a rule, to electrolytic dissociation of the surface of one phase, in which the one ion, owing to its insolubility, remains fixed at the surface, while the opposite ion, although soluble, cannot wander away further than permitted by electrostatic attraction. Thus we have a Helmholtz double layer produced.

Before we pass on to consider how these phenomena intervene in physiological processes, there is one fact that should be referred to on account of its significance in connection with the contractile force of muscle. Surface tension is found to *decrease* as the temperature rises, or, as it is sometimes put, it has a negative temperature coefficient. This is unusual; but, if we remember that the interface between a liquid and its vapour disappears when the temperature rises to the critical point and, with it, of course, all phenomena at the boundary surface, the fact is not surprising that there is a diminution of these phenomena as the critical temperature is approached.

Perhaps that result of surface energy known as 'adsorption' is the one in which the conditions present at phase boundaries make themselves most frequently obvious Since the name has been used somewhat loosely, it is a matter of some consequence to have clear ideas of what is meant when it is made use of. Unless it is used to describe a definite fact, it can only be mischievous to the progress of science

Permit me, then, first to remind you of that fact of universal experience, known as the 'dissipation of energy,' which is involved in the second law of energetics. Free energy—that is, energy which can be used for the performance of useful work—is invariably found to diminish if the conditions are such that this is possible. If we have, therefore, a system in which, by any change of distribution of the constituents, free energy can be decreased, such a change of distribution will take place. This is one form of the well-known 'Principle of Carnot and Clausius.'

Now, practically any substance dissolved in water lowers the surface tension present at the interface between the liquid and another solid or liquid phase with which it is in contact. Moreover, up to a certain limit, the magnitude of this effect is in proportion to the concentration of the solute. Therefore, as was first pointed out by Willard Gibbs, concentration of a solute at an interface has the effect of reducing free energy and will therefore occur. This is adsorption. As an example, we may take the deposition of a dye-stuff on the surface of charcoal, from which it can be removed again, unaltered, by appropriate means, such as extraction with alcohol. Charcoal plus dye may, if any satisfaction is derived from the statement, be called a compound. But, since its chemical composition depends on the concentration of the solution in which it was formed, it is much more accurate to qualify the statement by calling it an

'adsorption-compound.' Moreover, the suggestion that the union is a chemical one tends to deprive the conception of chemical combination of its characteristic quality, namely, the change of properties. Dye-stuff and charcoal are chemically unchanged by adsorption.

The origin of adsorption from surface tension is easily able to explain why it is less as the temperature rises, as we find experimentally. As we have just seen, surface tension diminishes with increase of temperature.

Let us next consider what will happen if the liquid phase contains in solution a substance which lowers surface tension and is also capable of entering into chemical reaction with the material of which the other, solid, phase consists. For example, a solution of caproic acid in contact with particles of aluminium hydroxide. On the surface of the solid, the concentration of the acid will be increased by adsorption and, in consequence, the rate of the reaction with it will be raised, according to the law of mass action. Further, suppose that the liquid phase contains two substances which react slowly with each other, but not with the solid phase. They will be brought into intimate contact with each other on the surface of the solid phase, their concentration raised and the rate of their interaction increased. One of the reagents may clearly be the solvent itself. But in all these cases the rate of the reaction cannot be expressed by a simple application of the law of mass action, since the active masses are not functions of the molecular concentrations, but of the surface of the phase boundaries. The application of these considerations to the problem of the action of enzymes and of heterogeneous catalysis in general will be apparent. That the action of enzymes is exerted by their surfaces is shown, apart from the fact that they are in colloidal solution, by the results of experiments made in liquids in which the enzymes themselves are insoluble in the usual sense, so that they can be filtered off by ordinary filter paper and the filtrate found to be free from enzyme. Notwithstanding this insolubility, enzymes are still active in these liquids The statement has been found, up to the present, to apply to lipase, emulsin, and urease, probably to trypsin, and the only difficulty in extending it to all enzymes is that of finding a substrate soluble in some liquid in which the enzyme itself is not. That adsorption is a controlling factor in the velocity of enzyme action has been advocated by myself for some years, but it is not to be understood as implying that the whole action of enzymes is an 'adsorption phenomenon,' whatever may be the meaning of this statement. The rate at which the chemical reaction proceeds is controlled by the mass of the reagents concentrated on the surface of the enzyme phase at any given moment, but the temperature coefficient will, of course, be that of a chemical reaction.

The thought naturally suggests itself, may not the adsorption of the reacting substances on the surface of the enzyme suffice in itself to bring about the equilibrium at a greater rate, so that the assumption of a secondary chemical combination of a chemical nature between enzyme and substrate may be superfluous? I should hesitate somewhat to propose this hypothesis for serious consideration were it not that it was given by Faraday as the explanation of one of the most familiar cases of heterogeneous catalysis, namely, the union of oxygen and hydrogen gases by means of the surfaces of platinum and other substances. The insight shown by Faraday into the nature of the phenomena with which he was concerned is well known and has often caused astonishment. Now, this case of oxygen and hydrogen gases is clearly one of those called 'catalytic' by Berzelius. The fact that the agent responsible for the effect did not itself suffer change was clear to Faraday I would also, in parenthesis, call attention to the fact that he correctly recognised the gold solutions which he prepared as suspensions of metallic particles, that is, as what we now call colloidal solutions. Although the systematic investigation of colloids, and the name itself, were due to Graham, some of the credit of the discovery should be given to the man who first saw what was their nature. Adsorption, again, was accurately described by Faraday, but without giving it a name.

I confess that there are, at present, difficulties in the way of accepting concentration by adsorption as a complete explanation of the catalytic activities of enzymes. It is not obvious, for example, why the same enzyme should not be able to hydrolyse both maltose and saccharose, as it is usually expressed.

Another difficulty is that it is necessary to assume that the relative concentration of the components of the chemical system must be the same on the surface of the enzyme as it is in the body of the solution; in other words, the adsorption of each must be the same function of its concentration. Unless this were so, the equilibrium position on the enzyme surfaces, and therefore in the body of the solution, would be a different one under the action of an enzyme from that arrived at spontaneously or brought about by a homogeneous catalyst such as an acid. This consideration was brought to my notice by Professor Hopkins and requires experimental investigation. We know, indeed, that in some cases there is such a difference in the position of the equilibrium position, for which various explanations have been suggested. But it would be a matter of some interest to know whether this difference has any relation to different degrees of adsorption of the components of the system.

At the same time, adsorption is under the control of so many factors, surface tension, electrical charge, and so on, that the possibilities seem innumerable. There are, moreover, two considerations to which I may be allowed to call your attention. Hardy has pointed out that it is probable that the increased rate of reaction at the interface between phases may be due, not merely to increased concentration as such, but that in the act of concentration itself molecular forces may be brought into play which result in a rise in chemical potential of the reacting substances. In the second place, Barger has shown that the adsorption of iodine by certain organic compounds is clearly related to the chemical composition of the surfaces of these substances, but that this relationship does not result in chemical combination nor in abolition of the essential nature of the process as an adsorption. It would appear that those properties of the surface, such as electric charge and so on, which control the degree of adsorption, are dependent on the chemical nature of the surface. This dependence need not cause us any surprise, since the physical properties of a substance, inclusive of surface tension, are so closely related to its chemical composition.

There is one practical conclusion to be derived from the facts already known with regard to enzymes. This is, that any simple application of the law of mass action cannot lead to a correct mathematical expression for the rate of reaction, although attempts of this kind have been made, as by Van Slyke. The rate must be proportional to the amount of substrate adsorbed, and this, again, is a function both of the concentration of the substrate and of that of the products. It is, then, a continuously varying quantity. Expressed mathematically, the differential equation for the velocity must be something of this kind :

$$\frac{dC}{dt} = KC^n$$

where n itself is an unknown function of C, the concentration of the substrate or products.

The hypothesis of control by adsorption gives a simple explanation of the exponential ratio between the concentration of the enzyme and its activity, which is found to be different numerically according to the stage of the reaction. At the beginning, it may be nearly unity, in the middle it is more nearly 0·5, as in the so called 'square root law' of Schutz and Borissov, which is, however, merely an approximation. Simple explanations are also given of the fact that increasing the concentration of the substrate above a certain value no longer causes an increased rate of reaction. This is clearly because the active surface is saturated. Again, the effect of antiseptics and other substances which, by their great surface activity, obtain possession of the enzyme surfaces, and thereby exclude to a greater or less degree the adsorption of the substrate, receives a reasonable account. In many cases, the depressant or favouring action of electrolytes, including acid and alkali, is probably due to aggregation or dispersion of the colloidal particles of the enzyme, with decrease or increase of their total surface. It is to be noted that such explanations are independent of any possible formation of an intermediate compound between enzyme and substrate, *after* adsorption has taken place.

There is a further way in which adsorption plays a part in the chemical processes of cells, including those under the influence of catalysts. It is a

familiar fact that the concentration of water plays a large part in the position of equilibrium attained in reversible reactions of hydrolysis and synthesis. A synthetic process is brought about by diminution of the effective concentration of water. There are, doubtless, means of doing this in the elaborate mechanisms of cell life, and, in all probability, it is by adsorption on surfaces, which are able to change their 'affinity' for water.

I pass on to consider briefly some other cases in which the phenomena at phase boundaries require attention.

Let us turn our gaze from the interior of the cell to the outer surface, at which it is in contact with the surrounding medium. From the nature of adsorption there can be no doubt that, if the cell or the surrounding liquid contains substances which decrease surface energy of any form, these constituents will be concentrated at the interface. There are many such substances to be found in cells, some of lipoid nature, some proteins, and so on. Further, the experiments of Ramsden have shown that a large number of substances are deposited in surface films in a more or less rigid or solidified form. We are thus led to inquire whether these phenomena do not account for the existence of the cell membrane, about which so much discussion has taken place. We find experimentally that there are facts which show that this membrane, under ordinary resting conditions, is impermeable to most crystalloids, including inorganic salts, acids, and bases. There is no other explanation of the fact that the salts present in cells are not only in different concentration inside from that outside, but that there may be absence of certain salts from one which are present in the other, as, for example, sodium in the plasma of the rabbit not in the corpuscles. Moreover, the experiments of Hoeber have shown that electrolytes are free in the cells, so that they are not prevented from diffusion by being fixed in any way. The mere assumption of a membrane impermeable to colloids only will not account for the facts, since, as I have shown in another place, this would only explain differences of concentration, but not of composition. The surface concentration of cell constituents readily accounts for the changes of permeability occurring in functional activity, since it depends on the nature of the cell protoplasm and chemical changes of many and various kinds occur in this system. If such be the nature of the cell membrane, it is evident that we are not justified in expecting to find it composed of lipoid or of protein alone. It must have a very complex composition, varying with the physiological state of the cell. Indeed, complex artificial membranes have been prepared having properties very similar to that of the cell.

This view that the membrane is formed by surface condensation of constituents of the cell readily accounts for the changes of permeability occurring in functional activity, since its composition depends on that of the cell protoplasm, and chemical changes of various kinds take place in this system, as it is scarcely necessary to remind you. In fact, the cell membrane is not to be regarded as an independent entity, but as a working partner, as it were, in the business of the life of the cell. In the state of excitation, for example, there is satisfactory evidence that the cell membrane loses its character of semi-permeability to electrolytes, &c. This statement has been shown to apply to muscle, nerve, gland cells, and the excitable tissues of plants, as well as to unicellular organisms. We shall see presently how this fact gives a simple explanation of the electrical changes associated with the state of activity.

If, then, the cell membrane is a part of the cell system as a whole, it is not surprising to find that substances can affect profoundly, although reversibly, the activities of the cell, even when they are unable to pass beyond the outer surface. The state of dynamic equilibrium between the cell membrane and the rest of the cell system is naturally affected by such means, since the changes in the one component involve compensating ones in the other. Interesting examples of such actions are numerous. I may mention the effect of calcium ions on the heart muscle, the effect of sodium hydroxide on oxidation in the eggs of the sea-urchin, and that of acids on the contraction of the jelly-fish. Somewhat puzzling are those cases in which drugs, such as pilocarpine and muscarine, act only during their passage through the membrane and lose their effect when their concentration has become equal inside and outside the cell.

The work of Dale on anaphylaxis leads him to the conclusion that the

phenomena shown by sensitised plain muscle can most reasonably be explained by colloidal interaction on the surface of the fibres. The result of this is increased permeability and excitation resulting therefrom.

I referred previously to the electrical change in excitable tissues and its relation to the cell membrane. It was, I believe, first pointed out by Ostwald and confirmed by many subsequent investigators, that in order that a membrane may be impermeable to a salt it is not a necessary condition that it shall be impermeable to both of the ions into which this salt is electrolytically dissociated. If impermeable to one only of these ions, the other, diffusible, ion cannot pass out beyond the point at which the osmotic pressure due to its kinetic energy balances the electrostatic attraction of the oppositely charged ion, which is imprisoned. There is a Helmholtz double layer formed at the membrane, the outside having a charge of the sign of the diffusible ions, the inside that of the other ions. Now, suppose that we lead off from two places on the surface of a cell having a membrane with such properties to some instrument capable of detecting differences of electrical potential. It will be clear that we shall obtain no indication of the presence of the electrical charge, because the two points are equipotential, and we cannot get at the interior of the cell without destroying its structure. But if excitation means increased permeability, the double layer will disappear at an excited spot owing to indiscriminate mixing of both kinds of ions and we are then practically leading off from the interior of the cell, that is, from the internal component of the double layer, while the unexcited spot is still led off from the outer component. The two contacts are no longer equipotential. Since we find experimentally that a point at rest is electrically positive to an excited one, the outer component must be positive [illegible] membrane is permeable to certain cations, impermeable to the correspond[illegible] action on the cell such as would make the membrane permeable—[illegible] chemical agents, and so on—would have the same effect as the state [illegible] If we may assume the possibility of degrees of permeability, the sta[illegible] bition might be produced by *decrease* of permeability of the membr[illegible] cell, which was previously in a state of excitation owing to some inn[illegible] inherent in the cell itself or coming from the outside. This manner of accou[illegible] ing for the electromotive changes in cells is practically the same as that give[illegible] by Bernstein.

It will be found of interest to apply to secretory cells the facts to which I have directed your attention. If we suppose that the setting into play of such cells is associated with the production of some osmotically active substance, together with abolition of the state of semi-permeability of the membrane covering the ends of the cells in relation with the lumen of the alveolus of the gland, it is plain that water would be taken up from the lymph spaces and capillaries and escape to the duct, carrying with it the secretory products of the cells. This process would be continuous as long as osmotically active substances were formed. Such a process has been shown by Lepeshkin to occur in plants and we have also evidence of increased permeability during secretory activity in the gland cells of animals. From what has been said previously, it is evident that electrical differences would show themselves between the permeable and semi-permeable ends of such cells, as has been found to be the case.

As a modifiable structure, we see the importance of such a membrane as that described if it takes part in the formation of the synapse between neurones. The manifold possibilities of allowing passage to states of excitation or inhibition and of being affected by drugs will be obvious without further elaboration on my part.

Enough has already been said, I think, to show the innumerable ways in which phenomena at phase boundaries intervene in physiological events. Indeed, there are very few of these, if any, in which some component or other is not controlled by the action of surfaces of contact. But there is one especially important case to which I may be allowed to devote a few words in conclusion. I refer to the contractile process of muscle. It has become clear, chiefly through the work of Fletcher, Hopkins, and A. V. Hill, that what is usually called muscular contraction consists of two parts. Starting from the resting muscle, we find that it must have a store of potential energy, since we can make it do work when stimulated. After being used in this way, the store must be replenished, since

energy cannot be obtained from nothing. This restoration process is effected by an independent oxidation reaction, in which carbohydrate is burnt up with the setting free of energy which is made use of to restore the muscle to its original state. Confining our attention for the moment to the initial, contractile, stage, the essential fact is the production of a certain amount of energy of tension, which can either be used for the performance of external work or be allowed to become degraded to heat in the muscle itself. It was Blix who first propounded the view that the amount of this energy of tension is related to the magnitude of certain surfaces in the muscle fibres. But the fact was demonstrated in a systematic and quantitative manner by A. V. Hill. He showed, in fact, that the amount of energy set free in the contractile process is directly related to the length of muscle fibres during the development of the state of tension. In other words, the process is a surface phenomenon, not one of volume, and is directly proportional to the area of certain surfaces arranged longitudinally in the muscle. This same relationship has been shown by Patterson and Starling to hold for the ventricular contraction of the mammalian heart and by Kosawa for that of the cold-blooded vertebrate. It appears that all the phenomena connected with the output of blood by the heart can be satisfactorily explained by the hypothesis that the energy of the contraction is regulated by the *length* of the ventricular fibres during the period of development of the contractile stress. The degree of filling at the moment of contraction is thus the determining factor.

That surface tension itself may be responsible for the energy given off in muscular contraction was first suggested by Fitzgerald in 1878, and it seems, from calculations made, that changes at the contact surface of the fibrillæ with the sarcoplasm may be capable of affording a sufficient amount. The difficulties in deciding the question are great, but, in addition to the facts mentioned, there is other interesting evidence at hand. It has been shown, by Gad and Heymans, by Bernstein and others, that the contractile stress produced by a stimulus has a negative temperature coefficient. Within the limits of temperature between which the muscle can be regarded as normal, this stress is the greater the lower the temperature. The same statement was shown by Weizsacker (working with A. V. Hill) to hold for the heat developed in the contractile stage. Now, of all the forms of energy possibly concerned, that associated with phase boundaries is the only one with a negative temperature coefficient. Another aspect of this relation to temperature is the well-known increase of the tonus of smooth muscle with fall in temperature.

It is tempting to bring into relation with the change in surface tension the production of lactic acid. In fact, this idea was put into a definite statement by Haber and Klemensievich in 1909 in a frequently quoted paper on the forces present at phase boundaries The production of acid is stated to alter the electrical forces at this situation. This electrical charge involves a change of surface tension, and it is this change of surface tension which brings about the mechanical deformation of the muscle. Mines also has brought forward good evidence that the production of lactic acid is responsible for the change of tension. As to how the lactic acid is set free, and of what nature the system of high potential present in muscle may be, we require much more information. The absence of evolution of carbon dioxide when oxygen is not present shows that no oxidation takes place in the development of tension. There are other difficulties also in supposing that this system present in resting muscle is of a chemical nature. If the energy afforded by the oxidation of carbohydrate in the recovery stage is utilised for the formation of another chemical system with high energy content, the theory of coupled reactions indicates that there must be some component common to both systems. It is difficult to see what component of the muscle system could satisfy the conditions required. On the whole, some kind of system of a more physical nature seems the most probable. It it be correct that the oxidation of substances other than carbohydrate, fat for example, can afford the chemical energy for muscular contraction, as appears from the results of metabolism experiments, a further difficulty arises in respect to a coupled reaction. But the question still awaits investigation.

On the whole, I think that we may conclude that more study of the phenomena at phase boundaries will throw light on many problems still obscure. It would

probably not be going too far to say that the peculiarities of the phenomena called 'vital' are due to the fact that they are manifestations of interchange of energy between the phases of heterogeneous systems. It was Clerk Maxwell who compared the transactions of the material universe to mercantile operations in which so much credit is transferred from one place to another, energy being the representative of credit. There are many indications that it is just in this process of change of energy from one form to another that special degrees of activity are to be observed. Such, for example, are the electrical phenomena seen in the oxidation of phosphorus or benzaldehyde, and it appears that, in the photo-chemical system of the green plant, radiant energy is caught on the way, as it were, to its degradation to heat, and utilised for chemical work. In a somewhat similar way, it might be said that money in the process of transfer is more readily diverted, although perhaps not always to such good purpose as in the chloroplast. Again, just as in commerce money that is unemployed is of no value, so it is in physiology. Life is incessant change or transfer of energy, and a system in statical equilibrium is dead.

The following Reports and Papers were then read :—

1. *Report on Anæsthetics.*

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2. *Report on Electromotive Phenomena in Plants.*—See Reports, p. 218.

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3. *Report on the Structure and Function of the Mammalian Heart.*

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4. *Report on the Ductless Glands.*—See Reports, p. 217.

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5. *The Action of Light on certain Inorganic and Organic Substances.* *By* Professor BENJAMIN MOORE, *F.R.S.*

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6. *Some Fundamental Facts of Vision and Colour Vision.* *By* F. W. EDRIDGE-GREEN, *M.D., F.R.C.S.*

There are two assumptions, neither of which has any foundation in fact, which have made the interpretation of the facts of vision and colour vision very difficult if not impossible. These two assumptions are that the rods are percipient elements, and that there are definite specific fundamental sensations which by their mixture give rise to other sensations. The facts of vision and colour vision are directly opposed to both of these assumptions. There is no qualitative difference between the foveal region, in which only cones are present, and the para-foveal region, in which there are both rods and cones. The fact that the positive after-image can change its relative place in the field of vision whilst the eye remains unmoved shows that the photo-chemical stimulus must be outside the cones. It is difficult to imagine the photo-chemical substance situated in the cones, as how would this be regenerated, seeing there is no direct blood supply to the cones?

The assumption that there are fundamental colour sensations which by their mixture give rise to other colour sensations has also no foundation in fact. This assumption has made the fact that a colour-blind man can pass the wool test (as about 52 per cent. of dangerous cases can) unintelligible.

Recent writers who have endeavoured to explain the fact have tried to account for it on a so-called colour-blindness of the fovea. It is, however, quite easy to show that the colour-blindness is not limited to the fovea. A man whom I designate a trichromic will in favourable conditions make matches

similar to the normal, but in unfavourable conditions matches similar to a dichromic, and with small and dim lights he will confuse red with green. It is, however, easy to show that he is colour-blind in ordinary circumstances. When examined with my spectrometer he will declare that there are only three colours in the spectrum—red, green, and violet—and mark out the spectrum into about ten instead of eighteen monochromatic divisions. The pseudo-isochromatic tests show how defective his hue differentiation is as compared with the normal and that the defect is not limited to the fovea. Diminished hue discrimination accounts for these cases, the trichromic behaving in ordinary circumstances as a normal-sighted person in difficult circumstances. Even in those cases in which there is defective light-perception, as for instance shortening of the red end of the spectrum, this cannot be accounted for by a diminished red sensation, which is affected by other parts of the spectrum, as the shortening may be such that any amount of red light from the shortened region may be added to an equation without altering its appearance to the colour-blind.

7. *The Effect of Removal of the Post-central Gyri on the Movements of the Anthropoid Ape.* *By* Dr. T. Graham Brown.

8. *The Effect of Thyroidectomy and Thyroid-feeding on the Adrenin Content of the Supra-renals.* *By* Professor P. T. Herring.

THURSDAY, SEPTEMBER 9.

The following Papers were read :—

1. *The Mode of Action of Urease.*
By Professor W. M. Bayliss, *F.R.S.*

Urease is active in solutions in which it is insoluble—strong alcohol, for example. It, therefore, acts at its surface, and, presumably, by condensing urea on this surface, and increasing the rate of reaction with water by mass action, or perhaps by the intervention of molecular forces in the act of condensation.

This fact explains the effect of various substances on the rate of the reaction. This action may be of two kinds, one in changing the degree of colloidal dispersion and by this means the active surface, the other by taking possession of the surface and displacing the urea therefrom. Electrolytes have the former action, which may be either in increasing the dispersio and accelerating the reaction, or in aggregation and incipient precipitation, which results in retardation by decrease of the active surface. The former effect is shown by weak acid or phosphate. The latter is shown by multivalent ions, such as lanthanum.

The effect due to displacement of urea from the surface of the enzyme is shown by the so-called 'surface-active' substances, such as amyl alcohol, saponin, bile salts, &c. Since this effect is due to depression of surface energy, which has a negative temperature coefficient, it is interesting to find that the retardation in question is greater at low than at higher temperatures.

Another fact which is explained by the adsorption of urea by the surface of the enzyme is the exponential ratio between the concentration of the enzyme and its activity, together with the constancy of the rate of reaction above a certain concentration of the substrate. This last fact is due to the saturation of the surface, a very common circumstance in adsorption.

Concentrated solutions of urea have a remarkable retarding action, not only on urease, but on other enzymes. It is not to be explained by viscosity, since more viscous solutions of saccharose have not nearly so great an effect. This fact seems also to exclude the removal of water as an explanation. It is probably due to some action related to the solvent properties of urea to which Ramsden has called attention.

Attempts to obtain synthesis of urea from ammonium carbonate or bicarbonate by the agency of urease have been unsuccessful. The chemistry of the hydrolysis of urea is complex and involves several equilibria, in all of which the equilibrium position is very near that of complete hydrolysis. It is probable that the action of urease on urea is first to form ammonium cyanate, and experiments are in progress to investigate this. The change of ammonium carbamate to carbonate is not accelerated by urease.

The failure of urease to hydrolyse certain substituted ureas, such as urethane, is due to the fact that these substances do not undergo a spontaneous slow hydrolysis similar to that of urea, and they are not so readily attacked even by inorganic reagents. The absence of action is not therefore to be laid to the charge of the enzyme but to the peculiarity of the reactions themselves.

2. *Capillary Phenomena in Blood-Cells: Phagocytosis, &c.* *By* Dr. JOHN TAIT.

3. *Clinical Recognition of Excitatory Cardiac Disorders by the Electrocardiograph.* *By* Dr. C. E. LEA.

4. *The Alleged Acid Intoxication of Diabetic Coma.* *By* Dr. E. P. POULTON.

5. *Arginine and Creatine Formation.* *By* Professor W. H. THOMPSON.

6. *The Effects of Tetanization on the Creatine and Creatinine of the Muscles of the Cat.* *By* Professor W. H. THOMPSON, B. A. MCSWINEY, *and* W. FEARON.

7. *Demonstration of Electro-cardiograph Methods at Ancoats Hospital.* *By* Dr. C. E. LEA.

FRIDAY, SEPTEMBER 10.

The following Papers were read :—

1. *The Presence of Copper in Animal and Vegetable Tissues.* *By* Dr. C. POWELL WHITE.

2. *Microchemical Differentiation of Tissue Fats and Lipoids.* *By* Dr. F. W. LAMB *and* Mr J. HOLKER.

3. *Some Laws of Fat Absorption.* *By* Dr. F. W. LAMB.

4. *On the Liquid Pressure Theory of Muscular Contraction.* *By* SARAH M. BAKER, *D.Sc.*

None of the theories which have been put forward to explain muscular contraction gives a satisfactory correlation between the energy relations and the mechanism of the process.

The Liquid Pressure theory was worked out in consequence of a similar theory on the ascent of sap in plants. It was shown that, with the recognition of a new semipermeable membrane, impermeable to liquids but permeable to gases—the 'aeropermeable membrane'—the force of liquid pressure became available as a source of power. The force of liquid pressure under ordinary conditions is nullified by cohesion; but it has great magnitudes, being about 20,000 atmospheres per gramme for water at low temperatures.

According to this theory muscular contraction is caused by the respiration of glycogen through an aeropermeable membrane, according to the general equation :—

$$(C_6H_{10}O_5)\ n\ +6n\ O_2 = 6n\ CO_2+5nH_2O.$$

The liquid pressure which causes the contraction is due to the chemical production of water.

Macdougall's cytological observations of the process of contraction in the wing muscles of insects lend support to the view that an increase in the water content of the cells accompanies contraction. And this is also borne out by Maclendon's work on the changes in electrical conductivity of contracting muscles.

Further, the work of Overton and Meiggs on the osmotic properties of muscle shows that, although the entrance of water causes contraction, yet, while the muscle is still active, water as such cannot enter the cells. Hence the presence of an aeropermeable membrane has already been experimentally demonstrated in muscle. This is confirmed by Fletcher's work on fatigued muscles.

The reaction is to be regarded as a 'floating' respiration superimposed upon the normal respiration of the cells, analogous to the carbohydrate respiration observed by F. F. Blackman in leaves. The function of nervous or electric excitation is that of a stimulus which liberates some essential part of the reacting complex.

The physics of liquids has not been sufficiently worked out to enable an exact calculation of the energy balance of the reaction to be made. But at least forty-five per cent of the chemical energy evolved during respiration may be directly converted into liquid pressure by means of the aeropermeable membrane. Broca's 'travail physiologique' is in fact liquid pressure, and the name is not inapt, for the use of this form of energy is at present confined to living organisms.

The relaxation of muscles is explained as being due to the re-evaporation of water through the membrane. This process requires heat, and would absorb nine per cent. of the total energy of the respiration reaction, thus serving to reduce the excessive heat evolved.

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5. *The Elasticity of the Strophanthinised Heart.* *By* Dr. J. Tait *and* Dr. Harold Pringle.

SUBSECTION OF PSYCHOLOGY.

WEDNESDAY, SEPTEMBER 8.

The following Papers were read :—

1. *Behaviourism.* *By* Arthur Robinson, *M.A., D.C.L.*

Behaviourism is the view that 'consciousness is behaviour,' and that psychology is 'the science of behaviour.' It appears to have originated partly from a desire to make the subject-matter of psychology more 'objective' by limiting it

to events which may be witnessed by more than one observer, so bringing it into line with other natural sciences. This may be called the scientific motive of behaviourism. But it has a philosophic motive, too, and is part of the reaction against subjective Idealism.

Behaviourism is a position which admits of many degrees; it may imply an absolute rejection of all introspective data and the reduction of human to the same position as animal psychology; or it may be used merely to indicate the crude problem which it is the business of psychology to tackle.

The difficulty of defining psychology is notorious, but the history of the attempts shows that they have been intended to avoid philosophical implications and to avoid answering questions by implication at the beginning which can only be answered at the end. So psychology with a soul gave way to psychology without a soul, but with states or processes of consciousness. Now we are invited to discard minds or consciousness as the subject-matter of psychology and to substitute behaviour.

The term is highly ambiguous. It cannot mean merely biological or physiological behaviour. It ought not to mean mental behaviour, for then it would depend for its significance on the very notion which it is intended to replace. The processes which take place between the immediate bodily stimulus and the bodily response are undeniable happenings which cannot be described in physiological or biological terms.

Introspection in some sense is essential. But it does not imply an 'absolutely private mind' in any sense which would preclude common knowledge. Nor is it necessarily 'reflective'; having a pain and being conscious of having a pain are the same thing.

The data of introspection may be confirmed. And it is irrelevant to say that the object is not numerically identical for each observer respectively and for me. It is not the circumstance that certain events can be observed or immediately apprehended by only one individual that makes these facts mental. This circumstance is, in principle, purely accidental, and the facts are mental because they are different in nature from physical facts.

'Consciousness' is, no doubt, an ambiguous term, so is 'mind.' But they are both susceptible of explicit limitations by the aid of which they can indicate the subject-matter of psychology with sufficient accuracy for an initial definition. This subject-matter turns out to be much the same as that intended by the moderate behaviourist, but he puts the emphasis on that which is least characteristic. In short, Behaviourism brings forward no new class of facts, nor does it shed light on old facts. Its tendency is rather towards obscuring than elucidating the problems of psychology, while to establish its extreme position it has got to reduce processes usually called mental to biological or physiological processes and leave no remainder

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2. *The Relations between Magic and Animism.*

By Carveth Read, *M.A.*

It must be matter of conjecture which of these complexes of belief first arose Their origins were independent. Magic is the more uniform and persistent; and, on the hypothesis that it was the earlier, we may trace the following influences upon Animism:

(1) Many beliefs and practices are prepared according to magical ideas, and then adopted and modified by Animism:

(*a*) The idea of invisible force that may act at a distance, first connected with charms, spells, and rites, becomes the essence of the ghost and of all spiritual power.

(*b*) Magic things (charms) are explained when the ghost-theory arises, as owing their powers to in-dwelling spirits. The only difference is that their action now depends upon the spirits' will and caprice.

(*c*) Omens, at first magical coincidences, come to be explained as sent by gods.

(*d*) Spells addressed to objects become prayers to their presiding spirits; and magic rites become religious.

(2) As men in the flesh know Magic, so do their ghosts, and all demons or gods derived from ghosts or imagined by analogy with them. Hence: (*a*) Spirits teach Magic; (*b*) assist at Magic rites; (*c*) depend upon Magic for their own power. (*d*) Black Magic is merely unauthorised Magic, assisted by evil spirits.

(3) By retrogradation, after spiritual intervention has long been recognised, it may again be forgotten; so that a fetish again becomes a charm; a prayer, a spell, &c.

(4) The purpose of Magic is to obtain power over events, and the certainty of power. When spirits are believed in, they are propitiated for the same end. But their caprice is an abatement of certainty. Then arises the belief that they may be controlled by Magic, as the development of several religions shows us. For the only ground of certainty is uniformity.

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3. *Philosophy and the War.* *By* Dr. Wildon Carr.

THURSDAY, SEPTEMBER 9.

The following Papers were read :—

1. *On the Special Interests of Children in the War at Different Ages.* *By* C. W. Kimmins, *M.A., D.Sc.*

In order to obtain information as to the special interests of children at different ages in regard to the War, essays were written by all the children in ten senior departments (five boys' and five girls') of elementary schools No preparation was allowed and no notice given. The children were told to write as much as they could about the War in fifteen minutes. No child was allowed to exceed the time-limit.

In all, 3,081 papers were written, 1,511 boys, 1,570 girls. In order to obtain as far as possible the real interests and ideas of the children, the common material in the various groups, indicative of lessons or talks on the subject by the teachers, was carefully eliminated.

In spite of a large amount of overlapping in the interests and ideas at different stages, it was possible to group them broadly according to the ages of the children.

The results of the investigation are classified under six age-groups (8 to 14) corresponding to the ages of children in the senior departments of elementary schools. The main interests of boys and girls are given separately in each age-group. It was found on examination to be better to group them according to mental ages. Thus, in the eight-year-old group there were some backward children of ten, eleven, and twelve years of age, and occasionally clever children of seven. In such a group a large majority of the children were eight years of age, and the comparatively few older and younger children were always taught with them. It was interesting to notice that the interests of these older or younger children did not differ materially from those of the normal age for the group.

Not only do the interests of boys and girls vary for each particular group, but the nature of the variations which appeared in passing up through the school varies also with sex.

The fact that emerges most clearly from the investigation is the bellicose attitude of the girls of ten, the wave of depression at eleven, and the establishment of normal interests at twelve years of age. The boys, on the other hand, become more warlike at eleven, and, though a period of slight depression follows upon this, it is much less marked than in the case of the girls.

The references apart from those to the origin of the War are almost entirely confined to the incidents happening within a comparatively short time of the date on which the essays were written. Such important events as the march on Paris, the retreat from Mons, and the battle of the Marne receive no attention. Matters distant in time or place appear to have little interest for young children.

Curious instances are given of the extraordinary impressions produced upon children by new experiences, and interesting sidelights are obtained of discussions on the War overheard at home. The passage from matters of local to those of general interest as the age increases is very marked. Not a single member of the Cabinet is mentioned with the exception of Lord Kitchener, to whom, especially in the boys' essays, constant reference is made.

From the age of eleven onwards great anxiety is felt with regard to the price of food, and the excessive interest taken in the operations in the Dardanelles is clearly due to the supposed connection of the free passage to the Black Sea with the price of food.

The most interesting results are (1) the clearly marked change of interest from age to age; (2) the radical difference between the interests of boys and those of girls up to the age of twelve; and (3) the maturity of ideas on such a subject as the War at the age of thirteen, more especially in the case of girls, who are in this respect at least a year ahead of the boys.

The methods of expressing ideas from age to age are touched upon

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2. *An Attempt to trace the Course of the Development of some Mental Capacities by the Application of Mental Tests to Children from Five to Fifteen Years of Age.* By Miss M. E. Bickersteth

1. The possibility of establishing by means of mental tests reliable age norms graded by years. The work of Binet and Simon

2. Subjects of the Experiment.

Group I.	500.	Girls.	Oxford Higher Elementary Schools.
II.	300.	Girls.	Secondary Schools.
III.	150.	Boys and Girls	Oxfordshire Village Schools.
IV.	300.	Boys and Girls.	Ripon Elementary Schools.
V.	500.	Boys and Girls.	Leeds Elementary Schools.
VI.	500.	Boys and Girls.	Yorkshire Dales Elementary Schools.

3. Apparatus Procedure, and Results of the several Tests.

List of Tests.

1. Precision and Speed of Movement (Plunger)	Motor Tests
2. Power of Sustained Effort (Tapping)	Motor Tests
3. Alphabet Test	Tests of Discriminative Selection.
4. Number Test	Tests of Discriminative Selection.
5. Combined Test	Tests of Discriminative Selection.
6. Memory for Narrative	Memory Tests.
7. Memory for Related Words	Memory Tests.
8. Memory for Unrelated Words	Memory Tests.
9. Spot Pattern Repeated	Test of Analytic and Synthetic Apperception.
10. Discriminative Reaction	Attention Tests.
11. Discs and Sentences	Attention Tests.
12. Completion of Analogies	Reasoning Test.

4. Deductions.
   1. The Correlation between Mental and Physical Age.
   2. The Ages at which Mental Capacities show Changes in Development.
   3. The Correlation of Mental and Motor Ability.
   4. The Variation with Age in the Correlation of different Mental Capacities.
   5. The Mental Differences between Town and Country Children.

5. General Conclusions as to the Value of Mental Tests to Show the Increase of Capacity with Age.

TABLE I.

Oxford Higher Elementary Schools, Girls. Summary of Averages.

Age	Motor Tests		Discriminative Selection		Memory				Attention		Analytic and Synthetic Apperception	Reasoning
	Speed and Precision of Movement	Tapping	Alphabet	Number	Combined A. and N.	Mem. for Narrative	Related Words	Unrelated Words	Dotting	Discs and Sentences	Spot Pattern	Analogies
5.5	28¾″	172·9	3·4	2·7					15			
6·5	24⅞″	185·2	3·0	4·6					27			
7·5	24⅜″	199·3	6·9	5·8					37	41·6″		
8·5	21½″	209·8	6·8	7·7	14·9	16·5			54	40·8″	11·1	
9·5	19⅝″	240·7	9·3	9·5	18·5	16·9	13·9		67	36·7″	12·0	28·8
10·5	19⅜″	259·2	11·7	9·4	19·6	18·6	13·8	4·3	71	34·0″	12·5	34·0
11·5	18″	266·2	11·9	12·3	22·4	22·1	13·9	3·7	96	32·7″	13·1	39·8
12·5	17″	281·7	11·2	11·0	27·6	21·4	13·8	5·0	112	25·9″	13·6	43·0
13·5	17⅛″	288·5	11·3	13·4	27·2	23·5	14·6	5·7	118	29·4″	14·3	45·1
14·5	17⅛″	301·4	13·6	15·4	30·5	22·7	15·3	8·0	139	24·7″	15·8	46·6
15·5	—	297·7	14·7	17·2	31·5	22·1	—	6·0	142	24·3″	16·4	51·8

3. *Some Problems of Fatigue.* By Miss MAY SMITH.

1. The difficulty of obtaining an adequate measure of fatigue and of standardising its application.

2. Before attempting to measure the probably small amount of fatigue engendered by specialised work for a limited time it is necessary to get an objective measure when fatigued conditions are assured.

3. The immediate and delayed effects of fatigue due to considerable loss of sleep, as measured by :

(*a*) the Rivers—McDougall dotting machine.
(*b*) the reproduction of lists of associated words.
(*c*) the combination of (*a*) and (*b*).
(*d*) the learning and relearning of nonsense syllables.

4 The effect of fatigue on the capacity for work when there are already fatigue symptoms, as opposed to its effect on the normal state.

5. The results of successive experiments involving the same loss of sleep giving indication of partial immunity.

4. *The Educational Significance of Modern Psychological Research upon the Thought-processes.* By T. H. PEAR.

5. *A Record of Feeling in Everyday Life.* By J. C. FLÜGEL, *B.A.*

A systematic record of feelings experienced in everyday life would seem to be of considerable interest, both from the standpoint of pure and applied Psychology and from that of Philosophy (especially of Ethics).

The difficulties which have to be overcome in any attempt to make such a record depend chiefly upon the illusions of memory which occur as regards affective experiences. The nature and extent of these illusions make it imperative that the entries composing the record should be made as frequently as possible in the course of the period under observation.

A record of this character has been kept by one subject for a period of thirty days (excluding a considerable period of preliminary practice). It affords information :—

(1) as to the relative proportions of Pleasure, Unpleasure and Indifference experienced by the subject,
(2) as to the relative frequency of different intensities of Pleasure and Unpleasure,
(3) as to the relative frequency of different moods and emotions and the nature and intensity of the Pleasure or Unpleasure accompanying them.

Similar records kept by a number of individuals would probably throw interesting light upon certain problems connected with individual differences and mental 'make-up.'

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6. *The Study of Character by Exact Methods: its Possibility and Difficulties.* By E. Webb.

1. Meaning of 'exact methods' : the obtaining of some kind of measurements of character-qualities and submitting them to controlled statistical examination.

[The powerful weapon of statistical mathematics only just beginning to be recognised in psychology ; the same mathematical propositions have furnished the basis of actuarial work, upon which the stability of all Insurance business depends.]

2. The Possibility of such a Procedure.—The ability to 'estimate' qualities is more reliable than is generally supposed (evidence will be submitted)—it would seem to be an essential part of our equipment for 'social safety.' In actual life these estimates are biased in various ways ; in scientific work the bias can and must be eliminated, or measured. Further, standardised 'tests' (comparable with the present use of 'intelligence tests') in the nature of definitely arranged situations could be devised.

3. Its Difficulties.

(*a*) To obtain a sufficiently numerous group of suitable subjects for prolonged observation and subsequent judgment. Schools, colleges, clinics, hospitals, soldiers' and sailors' headquarters, &c.

(*b*) To select judges who can make a prolonged all-round observation and study of the subjects. This must be entirely unknown to the latter.

(*c*) To eliminate bias : personal prejudices of the judges : independence of the work of studying and of estimating.

(*d*) To choose a scale of measurement : suggested sevenfold grouping with the average of the group as the central class ; difficulty of 'distribution'—suggestion of an assumed 'regular' distribution of normal type as a tentative starting-point.

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7. *General and Specific Factors underlying the Primary Emotions.* By Cyril Burt.

A. *Methods of Estimating Emotional Tendencies.*

1. *Method of Direct Judgment.*—The person judging one subject to be more angry, timid, &c., than another (or than the average) bases his estimates simply on direct impressions and simple observation. This method has been used in most studies of character-qualities hitherto. But, as in other investigations dealing with personal judgments, the results obtained necessarily measure the capacities of the persons judging rather than the qualities of the persons judged.

2 *Method of Indirect Estimate.*—Selected items of behaviour are systematically recorded in a way comparable for all members of the group observed. Certain items are classed together as representing certain tendencies. From the number, intensity, frequency, duration, and after-effects of the several reactions are calculated arbitrary measures of the hypothetical tendencies. The facts observed are thus kept distinct from the estimates inferred from them.

B. *Results of Investigations upon Children and Adults.*

1. The Method of Indirect Estimate gives far higher reliability coefficients, ranging usually from ·60 to ·70 as against ·45 to ·50; and generally gives results more consonant with those of general experience and of research in other special directions (*e.g.*, rarity of negative correlations).

2. The intercorrelations between estimates of the several primary emotions (McDougall's list enlarged) commonly exhibit a hierarchical arrangement (see Table I.), and suggest the presence of a general factor common to all the primary emotions, which in turn may be independently identified with 'general emotionality.'

TABLE I.

Observed Coefficients. 172 *normal children aged* 9-12.

—	Sociality	Sorrow	Tenderness	Joy	Wonder	Elation	Disgust	Anger	Sex	Fear	Subjection
Sociality	—	·83	·81	·80	·71	70	·54	·53	·59	·24	·13
Sorrow	·83	—	·87	·62	·59	·44	·58	·44	·23	·45	·21
Tenderness	·81	·87	—	·63	·37	·31	·30	·12	·33	·33	·36
Joy	·80	·62	·63	—	·49	·54	·30	·28	·42	·29	−·06
Wonder	·71	·59	·37	·49	—	·54	·34	·55	·40	·19	·10
Elation	·70	·44	·31	·54	·54	—	·50	·51	·31	·11	·10
Disgust	·54	·58	·30	·30	·34	·50	—	·38	·29	21	·08
Anger	·53	·44	·12	·28	·55	·51	·38	—	·53	·10	−·16
Sex	·59	·23	·33	·42	·40	·31	·29	·53	—	−·09	−·10
Fear	·24	·45	·33	·29	·19	·11	·21	·10	−·09	—	·41
Subjection	·13	·21	·36	−·06	−·10	·10	08	−·16	−·10	·41	—
Average	·59	·53	·44	·43	·41	·40	·35	·33	·29	·22	·09
Hypothetical General Factor	·99	·90	·73	·69	·66	·65	·57	·52	·45	·35	·09
General Emotionality	·68	·56	·45	·62	·57	·53	·38	·64	·27	·19	−·14

TABLE II

Partial Coefficients. 329 *children and adults.* (*Average for five groups.*)

—	Joy	Sex	Sociality	Elation	Wonder	Anger	Disgust	Sorrow	Fear	Subjection	Tenderness
Joy	—	·21	·33	·21	·06	−·04	−·18	−·01	·01	−·13	·21
Sex	·21	—	·53	·02	·06	·25	−·18	−·06	−·24	·03	·15
Sociality	·33	·53	—	·34	·22	·07	·04	−·29	−·26	−·26	·15
Elation	·21	·02	·34	—	·38	·38	·30	−·30	−·23	−·09	−·19
Wonder	·06	·06	·22	·38	—	·34	−·15	·07	−·03	−·16	−·16
Anger	−·04	·25	·07	·38	·34	—	·23	·16	−·13	−·49	·31
Disgust	−·18	−·18	·04	·30	−·15	·23	—	·20	·16	−·19	−·13
Sorrow	−·01	−·06	−·29	−·30	·07	·16	·20	—	·28	·10	·34
Fear	·01	−·24	−·26	·23	−·03	−·13	·16	·28	—	·45	·11
Subjection	−·13	·03	−·26	−·09	−·16	−·49	−·19	·10	·45	—	·26
Tenderness	·21	·15	·15	−·19	−·16	−·31	−·13	·34	·11	·26	—

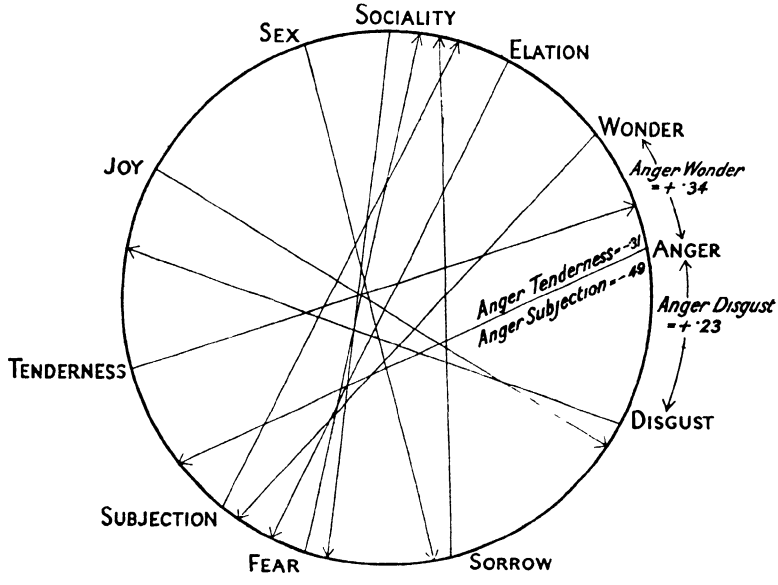
3. By means of 'partial correlation' the influence of the hypothetical general factor may be eliminated, and the partial or specific intercorrelations calculated.

The arrangement of these coefficients suggests a scheme which is not hierarchical, and has not hitherto been described. The positive coefficients form a diagonal line running from the top left-hand corner to the bottom right-hand corner (see Table II.), with outlying groups at the top right and bottom left corners : the negative coefficients run in lines parallel to the diagonal from the centre of the top row to the centre of the last column and from the centre of the first column to the centre of the bottom row.

This arrangement suggests that the specific tendencies may form a circular series, each member being most closely related to its immediate neighbour, less closely related to remoter members, and antagonistically related to members half-way round the cycle.

To illustrate the Chief Specific Correlations between the Chief Emotional Tendencies.

(Distances of arc represent inversely the chief positive correlations; chords represent the average direction of the chief negative correlations)



This phenomenon—the cyclic overlap of specific factors—has also been observed in partial coefficients obtained by eliminating 'general intelligence' from the intercorrelations of complex mental tests. It may, therefore, have a wide significance for the study of mental organisation.

The theory of a general factor is commonly associated with the views that specific factors are negligible and that the general factor is simple. The problem arises as to whether the above specific correlations invalidate the hypothesis of a general factor, and, in particular, whether the peculiar relations between the specific factors may not of themselves produce the appearance of a general factor. Independent evidence, however, appears to confirm the existence of both general and specific factors underlying emotional reactions and to Certainly that both are highly complex.

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FRIDAY, SEPTEMBER 10.

The following Papers were read :—

1. *The Use of Mental Tests for Measuring Mental Defect.* *By* A. R. ABELSON.

There is every reason to believe that in the future problems of race efficiency and of race superiority will receive paramount attention. It will be necessary to devise the most effective schemes for the weeding out (by segregation) of the unfit and for the securing of the highest standard possible of race culture.

The view expressed in Dr. Myers' 'Pitfalls of Mental Tests' has been corroborated. The evidence is strongly opposed to the opinion often tacitly and even avowedly accepted that no special training is necessary for carrying out examinations into mental defect. Satisfactory measurement of mind is impossible without scientific knowledge of the mind.

The Binet system possesses serious disadvantages which render it inadequate for the examination of defective children. Before any system of tests can hope to be satisfactory, the general principles must be determined for their scientific construction and use. The tests should be short, reliable, and straightforward. They should be within the range of the general experience of the child, but should not depend on scholastic training. It is of vital importance that the child should be made to feel perfectly at ease during the examination, and the conditions should be such as to evoke the greatest effort possible from the child.

Evidence has been obtained with regard to the essential nature of mental ability. All tends to confirm the belief in a 'general factor'; every mental activity depends partly on this general factor and partly on a particular nervous structure specially subserving the mental activity. This general factor, known as 'general ability' is best conceived as the individual's fund of 'intellective energy' free for use in any direction.

Mental Deficiency consists of a general lowering of all intellectual functions; in no case was it found to be distinctly localised. It appears to be a degradation of the above-mentioned intellective energy

Some children show abnormal brilliance at scholastic work and yet do not do correspondingly well at 'mental tests.' On the other hand, many children who are not good in the school work show signs of high general intelligence. It is evident from this that a child's scholastic ability is not always a fair criterion of his 'general ability.'

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2. *Notes on the Family Histories of Fifty Cases of Mentally Defective Children.* *By* Miss AGNES KELLEY.

These cases were taken without selection from the register of a Special School for Mentally Defective Children in the Haggerston district of the East end of London. The inquiry was made with a view of observing the relative amount of insanity, mental deficiency, epilepsy, alcoholism, and tuberculosis in the family histories, and also the occupation of the parents and the condition of the homes.

Occupation of the Parents.—Of the fathers, 17 were in regular trades, and of these only 5 in full-time regular work throughout the year. The greater number of the remainder were casuals and hawkers. Regular employment among the mothers only occurred in one or two cases.

Home Conditions.—Out of the fifty cases, in only about half-a dozen could the home conditions be described as good, even in comparison with the average home of the neighbourhood. A certain number were rendered poor by industrial conditions, but in by far the greater number, probably in at least three-quarters of the homes, the poverty was not only 'industrial,' but also 'degraded.'

Total Number of Family.—In some of the worst cases—those having two or more mental defectives in the same fraternity—the total number in family was

largest; the rates for deaths in infancy and still-births being correspondingly high.

Insanity occurred in the family histories of 15 of the children. There was only one case of an insane parent (a father). In 11 insanity was found in the grandparents, eight of these being on the paternal side.

Mental Deficiency.—Other cases of mental deficiency were found in 30 of the histories. In 19 cases two or more defectives appeared in the same fraternity, and in 17 one or other of the parents was mentally defective.

Epilepsy was found in the pedigrees of nine cases.

Alcoholism.—It is difficult in any way to measure the proportion of alcoholism among these, as compared with normal families, as it is obvious that they are more easily affected by drink. But in a large proportion of the cases the parents were such heavy drinkers that the mental defect was probably intensified. In one case (which it seemed probable was a case of retarded development) no other cause for the defect was observed.

Tuberculosis was very prevalent. The term 'consumption' is so generally and inaccurately used among the people that it would be useless to base any statement on the frequent 'died of consumption' reported. It is, however, apparent that these families are very liable to tuberculosis.

Throughout the whole of the pedigrees it was noticeable that both physically and mentally the general standard was 'below par' In many of the families there were members who could not strictly be termed 'defective,' yet were not by any means individuals of average health and ability. Such families cannot be compared in mental and bodily vigour with more normal stocks. They are wanting in initiative and are often inert and thriftless; the men low wage-earners, the women poor housewives; and they tend mentally and physically to be unfit to keep their place in the struggle for existence.

This type of mental deficiency appears to be more intensified in Haggerston than in the surrounding districts, which is due no doubt to the fact that it is a neighbourhood into which numbers of casuals, hawkers, part-time workers, and hangers on of more prosperous trades tend to drift (lasses of the community in which it is not surprising to find a lack of mental and physical stamina.

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3. *Perseveration.* By Ll. Wynn Jones.

The meaning of the term Perseveration, with special regard to the results of Muller and Pilzecker, Heymans and Wiersma, Heymans and Brugmanns, Culler, Foster, Lankes, Webb.

Various aspects; *e.g.*,

The perseveration of ideas. Should this be distinguished from association of ideas?

Sensory and motor perseveration.

Perseveration-qualities of character.

Is Perseveration a general factor, comparable with General Intelligence?

Correlation with Intelligence.

Methods of Measurement.

1. **Directly by noting the strength of the after-effect and the time for which it lasts.**
2. **By finding the degree of hindrance which the perseverating effect of a past mental activity causes to a new one of the same kind.**

Own Experiments.

(a) *Mass-tests.*

(1) 'i t test.'
(2) ? S test.
(3) Backward-stroke test.
(4) Mirror-image test.

(b) *Individual Tests.*

(1) Natural rate of tapping.
(2) After-images test.
(3) After-effect of seen movement.
(4) Pressure after-effect.

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4. *War and Sublimation.* By ERNEST JONES, *M.D.*

In the conduct of war, and implicit in the very conception of war, various impulses come to expression of a kind that are apparently non-existent, or at all events latent, in the same people during peace; they include, among others, such disapproved-of tendencies as cruelty, deceit, ruthless egotism, looting, and savagery of various kinds. These impulses are part of the inherited characteristics of mankind and are readily to be detected, though their significance is here greatly underestimated, in the mental life of the infant. In the course of individual development they are replaced by other tendencies of an opposite kind, such as consideration for others, honesty, altruism, and horror of cruelty. It is vulgarly believed that the primitive set disappears owing to the implantation or development of the more civilised kind, but psycho-analytical investigation shows that the process is more subtle and complex than this. The primitive tendencies never disappear from existence, they only vanish from view by being 'repressed' and buried in the unconscious mind. From here they exert a far more considerable influence on consciousness than might be imagined, and may also appear in an almost naked form in dream life when the possibility of external manifestation is excluded.

The main agent leading to the transformation in question is the pressure of education in the widest sense as exerted first by the parents and later on by the whole cultural environment as well, though no doubt the child is born with a susceptibility to this influence in the form of a 'predisposition.' The effects of this pressure comprise several distinct processes, the corresponding social significance of which is very different. In the first place may be mentioned 'sublimation,' *i.e.*, the replacement of an originally sexual aim by a more permissible, social, non-sexual one with the deflection of interest and energy from the former to the latter. Similar to this is the process whereby egotistic impulses become invested with erotic feeling (the word erotic is here used to cover all varieties of love) and in this way subordinated to the mutual interests of the individual and his environment. In both these cases we may speak of a 'refinement' of the primitive impulses, their very nature becoming profoundly affected. In contrast to this stand other effects of repression, which, although they may equally result in 'good' behaviour, do so merely through exercising an external pressure, there being no change whatever in the nature of the impulses. There are many varieties of this, compensations, character reactions, neurotic symptoms, &c., but they may all be grouped under the term 'pseudo-sublimation.' When the external cultural pressure is relaxed—as it officially is in time of war, for instance—there is a tendency to reversion in the direction of the primitive impulses, but this happens far more with the second group considered than with the first. The distinction between the two is essential to the understanding of various social phenomena, including war.

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5. *Observation and Formal Training.* By E. GLEAVES.

SATURDAY, SEPTEMBER 11.

The following Papers were read :—

1. *The Neuro-Psychoses of Adolescence.* By G. E. SHUTTLEWORTH, *B.A.*, *M.D.*

Adolescence (roughly from 15 to 25) opens a new chapter in life, sex differences being evolved and accentuated.

Influences of heredity in development, especially as regards latent tendencies. Emotional characters: risk of perversion. Neurotic accompaniments, *e.g.*, hysteria and epilepsy. Asocial peculiarities, *e.g.*, irritability of temper, family aversions, suspicions, religiosity, &c.

Developmental mental stress. The risks of competitive examinations. Fancied talent. Disappointment and its results.

Moral sense and its perversions, Hyper-conscientiousness, Romanticism, Untruthfulness, Dishonesty, unprincipled conduct, and experversions.

Devolutionary conditions. Juvenile General Paralysis of the Insane. Dementia præcox. Suicide.

2. *Therapeutic Re-education.* By Dr. JESSIE MURRAY.

3. *Some Effects of Training Children's Powers of Observation.* By Miss I. B. SAXBY.

In a little book called 'Methods of Mind Training' Miss C. Aiken describes a number of exercises in quick observation which are intended to develop in children the power of 'keeping the mind on the alert and holding the attention steadily.' She gave these exercises about twenty minutes a day and was much impressed by the improvement they produced, especially in the case of unintelligent children.

For the purpose of my experiment the exercises were given regularly fifteen minutes a day on four days of every week for a period of twelve weeks, and in connection with them an attempt was made to create a real desire to become more observant in the children who had these special lessons. The effect of this training was measured by means of four tests, of which three were given respectively at the beginning, middle, and end of the period of training, the fourth after a further period of four months. The material used in these tests consisted in (1) memory drawings of well-known objects, (2) reproduction of a story read to the class once only, and (3) reproduction of a list of ten numbers shown to the class for thirty seconds. The experiment was conducted in four elementary schools, and for the sake of comparison the tests were repeated at another set of four elementary schools where no special training was given.

The results obtained in this way can be summarised as follows:

(1) Under suitable conditions a well-marked and effective desire can be developed in this way, but the improvement produced is not in general permanent. In Test 4 the difference between the trained and the non-trained is no longer significant for the class as a whole.

(2) If the training in observation is conducted by means of prestige suggestion only the more intelligent tend to improve more rapidly than the less intelligent, but the reverse is the case if prestige suggestion is used in connection with the special exercises in quick observation.

(3) In questions testing the amount of knowledge acquired during the period of training the more suggestible tend to improve more rapidly than the less suggestible, but the reverse is the case when the task consists in reproducing material memorised in a limited amount of time in the presence of the experimenter.

(4) As a suggestive force the effect of the exercises is negative rather than positive.

(5) The improvement in the work of the trained classes was in the main due to the development of a desire to become more observant.

The effect produced by the special exercises was almost *nil.*

(*a*) The more intelligent children derived no benefit from them either during the period of training or afterwards.

(*b*) The less intelligent children did derive benefit from them during the actual period of training, but a twelve weeks' course of lessons was found to be insufficient to produce a permanent improvement of any significance.

4. *The Rôle of Specific Mental Factors in Imagery.* By E. GLEAVES.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION:—PROFESSOR W. H. LANG, F.R.S

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address:—

SINCE I am not a visitor to our place of meeting it is my privilege to extend to the members of this Section a special welcome on behalf of our Botanical Department.

The war has diminished for the time the number of those engaged in botanical work. I shall not attempt any mention of those botanists who are serving with the Forces, are assisting in the training of recruits, or are otherwise playing their parts in the service of the country. Some have been wounded, but, we rejoice to know, recovered. We have, however, to express our sorrow, tempered with pride, at the cutting short of the promising botanical careers of Mr. Laidlaw and Mr Lee, who have been killed at the Front.

While we have no group of foreign guests, as at the last Manchester meeting, we owe to the war the presence of a distinguished Belgian botanist, Professor Julius MacLeod, and shall hear some of the results of investigations he has made while in England. In welcoming him to this meeting we hope that he may soon be able to return to his own University of Ghent when the invaders are expelled from his country.

Phyletic and Causal Morphology.

I propose to deal with some aspects of the study of plant-morphology. In doing so I shall not accept any definition of morphology that would separate it artificially from other departments of botany. I regard the aim of plant-morphology as the study and scientific explanation of the form, structure, and development of plants. This abandons any sharp separation of morphology and physiology and claims for morphology a wider scope than has been customary for the past fifty years. During this period the problem of morphology has been recognised as being 'a purely historical one,' 'perfectly distinct from any of the questions with which physiology has to do,' its aim being 'to reconstruct the evolutionary tree.' The limitation of the purpose of morphological study, expressed in these phrases from the admirable addresses delivered to this Section by Dr. Scott and Professor Bower some twenty years ago, was due to the influence of the theory of descent. I fully recognise the interest of the phyletic ideal, but am unable to regard it as the exclusive, or perhaps as the most important, object of morphological investigation. To accept the limitation of morphology to genealogical problems is inconsistent with the progress of this branch of study before the acceptance of the theory of descent, and leaves out many of the most important problems that were raised and studied by the earlier morphologists.

In the history of morphology, after it had ceased to be the handmaid of the systematic botany of the higher plants, we may broadly distinguish an idealistic period, a developmental period, and a phyletic period. The period of developmental morphology, the most fruitful and the most purely inductive in our science, was characterised by an intimate connection between morphological and physiological work. Among its contributions were studies of development or 'growth histories' of whole plants and their members. These were carried out, in part at least, in order to investigate the nature of development, and such general problems found their expression at the close of the period in the 'Allgemeine Morphologie' of Hofmeister. The 'Origin of Species' took some years before it affected the methods and aims of botanical work. Then its effect on morphology was revolutionary and, as in all revolutions, some of the best elements of the previous régime were temporarily obscured. This excessive influence of the theory of descent upon morphology did not come from Darwin himself but from his apostle Haeckel, who gave a very precise expression to the idea of a genealogical grouping of animals and plants, illustrated by elaborate hypothetical phylogenetic trees. Such ideas rapidly dominated morphological work, and we find a special 'phylogenetic method' advocated by Strasburger.[1] The persistence of the phyletic period to the present time is shown not only in the devotion of morphology to questions of relationship but in the attempts made to base homologies upon descent only. Lankester's idea of homogeny can be traced to the influence of Haeckel, and nothing shows the consistency of phyletic morphology to its clear but somewhat narrow ideal so plainly as the repeated attempts to introduce into practice a sharp distinction between homogeny and homoplasy.

Professor Bower, in his Address last year and in other papers, has dealt illuminatingly with the aims and methods of phyletic morphology I need only direct attention to some aspects of the present position of this, which bear on causal morphology. The goal of phyletic morphology has throughout been to construct the genealogical tree of the Vegetable Kingdom. In some ways this seems farther off than ever. Phyletic work has been its own critic, and the phylogeny of the genealogical tree, since that first very complete monophyletic one by Haeckel, affords a clear example of a reduction series. The most recent and reliable graphic representations of the inter-relationships of plants look more like a bundle of sticks than a tree. Consider for a moment our complete ignorance of the inter-relationships of the Algæ, Bryophyta, and Pteridophyta. Regarding the Algæ we have no direct evidence, but the comparative study of existing forms has suggested parallel developments along four or more main lines from different starting-points in a very simple unicellular ancestry. We have no clue, direct or indirect, to the ancestral forms of the Bryophyta, and it is an open question whether there may not be as many parallel series in this group as in the Algæ. The Pteridophyta seem a better case, for we have direct evidence from fossil plants as well as the comparison of living forms to assist us. Though palæobotany has added the Sphenophyllales to the existing groups of Vascular Cryptogams and has greatly enlarged our conceptions of the others, there is no proof of how the great groups are related to one another. As in the Bryophyta, they may represent several completely independent parallel lines. There is no evidence as to what sort of plants the Pteridophyta were derived from, and in particular none that relates them to any group of Bryophyta or Algæ. I do not want to labour the argument, but much the same can be said of the seed-plants, though there is considerable evidence and fairly general agreement as to some Gymnosperms having come from ancient Filicales. The progress of phyletic work has thus brought into relief the limitations of the possible results and the inherent difficulties. As pointed out by Professor Bower, we can hope for detailed and definite results only in particularly favourable cases, like that of the Filicales.

The change of attitude shown in recent phyletic work towards 'parallel

[1] The claims of this phylogenetic method were at once criticised by Braun, in a form that deserves careful study to-day (*Monatsb. d. K. Akad. Wiss.* Berlin, 1875, p. 243 ff.).

developments in phyla which are believed to have been of distinct origin'[2] is even more significant. Professor Bower spoke of the prevalence of this as an 'obstacle to success,' and so it is if our aim is purely phyletic. In another way the demonstration of parallel developments constitutes a positive result of great value. Thus Professor Bower's own work has led to the recognition of a number of series leading from the lower to the higher Filicales. By independent but parallel evolutionary paths, from diverse starting-points in the more ancient Ferns, such similarity has been reached that systematists have placed the plants of distinct origin in the same genus. In these progressions a number of characters run more or less clearly parallel, so that the final result appears to be due 'to a phyletic drift that may have affected similarly a plurality of lines of descent.' This conclusion, based on detailed investigation, appears to me to be of far-reaching importance. If a 'phyletic drift' in the Ferns has resulted in the independent and parallel origin of such characters as dictyostely, the mixed sorus, and the very definite type of sporangium with a vertical annulus and transverse dehiscence, the case for parallel developments in other groups is greatly strengthened. The interest shifts to the causes underlying such progressive changes as appear in parallel developments, and the problem becomes one of causal morphology rather than purely historical.

The study of parallel developments would, indeed, seem likely to throw more light on the morphology of plants than the changes traced in a pure phyletic line, for it leads us to seek for common causes, whether internal or external. We cease to be limited in our comparisons by actual relationship, or forbidden to elucidate the organisation in one group by that which has arisen independently in another. Similarly the prohibition against comparing the one generation in the life-cycle with the other falls to the ground, quite apart from any question of whether the alternation is homologous or antithetic. The methods of advance[3] and the causal factors concerned become the important things, and if, for example, light is thrown on the organisation of the fern-plant by comparison with the gametophyte of the moss, so much the better. This, however, is frankly to abandon phylogeny as 'the only real basis of morphological study'[4] and with this any attempt to base homology on homogeny. Many of the homologies that exist between series of parallel development are what have been happily termed homologies of organisation; these are sometimes so close as to result in practical identity, at other times so distinct as to be evident homoplasies. The critical study of homologies of organisation over as wide an area as possible becomes of primary interest and importance.

Since about the beginning of the present century a change of attitude towards morphological problems has become more and more evident in several ways. It seems to be a phyletic drift affecting simultaneously a plurality of lines of thought. The increasing tendency to look upon problems of development and construction from a causal standpoint is seen in the prominence given to what may be termed developmental physiology and also in what Goebel has called Organography.[5] These deal with the same problems from different sides and

[2] This and other quotations in this paragraph are from Professor Bower's address to Section K in Australia (*Brit. Assoc. Rep.* 1914).

[3] In this connection it is of interest to remember that Professor Bower has always laid stress on the importance of studying methods of advance and has regarded in this way examples which some other morphologists have used to form an actual series. His use of the bryophyte sporogonium in explaining the origin of the sporophyte is a case in point. (Cf *Annals of Botany*, vol. viii., p. 344.)

[4] Strasburger, *Text Book of Botany*, p. 9. It would be truer to say that morphology has been the basis of phylogeny. If each is to be the basis of the other, the building can hardly progress!

[5] The special meaning attached by Goebel to Organography is difficult to ascertain and has undergone a fundamental change between the first and second editions of the *Allgemeine Organographie*. In the second edition (p. 8) the dependence of construction on function is regarded as open to question and in specific cases as untenable (p. 39). The justification for an Organography instead of a General Morphology would thus really disappear.

neither formulates them as they appear to the morphologist. Together with genetics, they indicate the need of recognising what I prefer to call General or Causal Morphology.

The problems of causal morphology are not new, though most of them are still unsolved and are difficult to formulate, let alone to answer. As we have seen, they were recognised in the time of developmental morphology, though they have since been almost wholly neglected by morphologists. So far as they have been studied during the phyletic period, it has been from the physiological rather than the morphological side. Still such problems force themselves upon the ordinary morphologist, and it is from his position that I venture to approach them. I willingly recognise, however, that causal morphology may also be regarded as a department of plant-physiology. In development, which is the essential of the problem, the distinction between morphology and physiology really disappears, even if this distinction can be usefully maintained in the study of the fully developed organism. We are brought up against a fact which is readily overlooked in these days of specialisation, that Botany is the scientific study of plants.

General morphology agrees with physiology in its aim being a causal explanation of the plant and not historical. Its problems would remain if the phyletic history were before us in full. In the present state of our ignorance, however, we need not be limited to a physico-chemical explanation of the plant. Modern physiology rightly aims at this so far as possible, but, while successful in some departments, has to adopt other methods of explanation and analysis in dealing with irritability. It is even more obvious that no physico-chemical explanation extends far enough to reach the problems of development and morphological construction. The morphologist must therefore take the complicated form and its genesis in development and strive for a morphological analysis of the developing plant. This is to attack the problem from the other side and to work back from the phenomena of organisation toward concepts of the nature of the underlying substance.

It is to these questions of general morphology with a causal aim (for causal morphology, though convenient, is really too ambitious a name for anything we yet possess) that I wish to ask your attention. All we can do at first is to take up a new attitude towards our problems, and to gather here and there hints upon which new lines of attack may be based. This new attitude is, however, as I have pointed out, a very old one, and in adopting it we re-connect [6] with the period of developmental morphology. Since the limited time at my disposal forbids adequate reference to historical details, and to the work and thought of many botanists [7] in this field, let me in a word disclaim any originality in trying to express in relation to some morphological problems what seems to me the significant trend, in part deliberate and in part unconscious, of morphology at present. The methods available in causal morphology are the detailed study in selected plants of the normal development and its results, comparison over as wide an area as possible with special attention to the essential correspondences (homologies of organisation) arrived at independently, the study of variations, mutations, and abnormalities in the light of their development, and ultimately critical experimental work This will be evident in the following attempt to look at some old questions from the causal point of view. I shall take them as suggested by the Fern without confining my remarks to this. The Fern presents all the main problems in the morphology of the vegetative organs of the higher plants, and what little I have to say regarding the further step to the seed-habit will come as a natural appendix to its consideration.

Individual Development.

Twice in its normal life-history the Fern exhibits a process of development starting from the single cell and resulting in the one case in the prothallus and in the other in the fern-plant. For the present we may treat these two

[6] It is no mere coincidence that modern genetics is due to the re-discovery of the work of an investigator of this period.

[7] It will be sufficient to mention the names of Knight, Naegeli, Leitgeb, Hofmeister, Vöchting, Sachs, Klebs, and Goebel as the earlier workers on this line.

stages in the life-history as individuals, their development presenting the same general problems as a plant of, say, *Fucus* or *Enteromorpha*, where there is no alternation of generations. How is the morphologist to regard this process of individual development?

In the first place we seem forced to regard the specific distinctness as holding for the germ as well as the resulting mature plant, however the relation between the germ-cell and the characters of the developed organism is to be explained. We start thus with a conception of specific substance,[8] leaving it quite an open question on what the specific nature depends. This enables us to state the problem of development freed from all considerations of the ultimate uses of the developed structure. The course of development to the adult condition can be looked upon as the manifestation of the properties of the specific substance under certain conditions. This decides our attitude as morphologists to the functions of the plant and to teleology. Function does not concern us except in so far as it is found to enter as a causal factor into the process of development. Similarly until purpose can be shown to be effective as a causal factor it is merely an unfortunate expression for the result attained.

Let me remind you also that the individual plant, whether it be unicellular, cœnocytic or multicellular, may behave as a whole at all stages of its development. We see this, for instance, in the germination of *Œdogonium*, in the germination and subsequent strengthening of the basal region in *Fucus* or *Laminaria*, in the moss-plant or fern-plant, or in a dicotyledonous tree. A system of relations is evident in the plant, expressed in the polarity and the mutual influences of the main axis and lateral branches, as well as in the influences exerted on the basal region by the distant growing parts We thus recognise, in its most general form, the correlation of parts, a concept of proved value in botany.

To some the expression of the observed facts in this way may appear perilously mystical I do not think so myself. It is true that the nature of the specific substance and of the system of relations is unknown to us, but it is regarded as a subject for scientific inquiry and further explanation. To recognise fully the complexity of the substance of the plant is not, however, a step towards neo-vitalism, but is perhaps our best safeguard against the dangers of this.

The wholeness of the individual, together with important phenomena of regeneration, has suggested the conclusion that something other than physico-chemical or mechanical laws are concerned in the development of the organism. To this something Driesch applies the name entelechy. Without discussing the vitalistic philosophy of the organism, or other modern phases of philosophic thought that treat life as an entity, it seems worth while to point out that they are based mainly on the consideration of animal development. It would be interesting to inquire into the difficulties that are met with in applying such views to plants, where regeneration in one form or another is the rule rather than the exception and often does not lead to restitution of the individual. Causal morphology can recognise phenomena of development and of the individual, which are at present beyond physico-chemical explanation, and try to attack them by any methods of investigation that seem practicable, without begging the main question at the outset and then proceeding deductively To assume any special inner director of development, be it entelechy or vital force, is to cut the knot that may ultimately be untied

The previous experience of botany in the time of nature-philosophy may well make us cautious of solving our difficulties by the help of any new biological philosophy. On the other hand, co-operation between biology and philosophic thought is highly desirable. In this connection I should like to refer to an idea contained in Professor Alexander's paper on the Basis of Realism.[9] He

[8] The more general concept of specific substance, which avoids hypotheses of heredity, seems preferable for our purpose to that of idioplasm or even of specific cell, since it leaves open the possibility of some properties of the plant being generalised in the protoplasm and not to be explained by the mutual relation of cells; it also covers the case of cœnocytic plants.

[9] Royal British Academy, Jan. 28, 1914, p. 12.

suggests that there is only one matrix from which all qualities arise, and that (without introducing any fresh stuff of existence) the secondary qualities, life, and, at a still higher level, mind, emerge by some grouping of the elements within the matrix. The development of this idea as it applies to life would appear to offer a real point of contact between inductive biological work and philosophy.

To return to our plant, its development, with increase in size and progressive complexity of external form and internal structure, must be considered. The power of continued development possessed by most plants and wanting in most animals makes comparison between the two kingdoms difficult. That there is no fundamental difference between the continued and the definitely limited types of embryogeny is, however, shown by plants themselves. The bryophyte sporogonium is a clear example of the latter, while the fern sporophyte is one of many examples of the former. A difference less commonly emphasised is that in the sporogonium (as in the higher animals) the later stages of development proceed by transformation of the whole of the embryo into the mature or adult condition; in the fern-plant the apical development results in successive additions of regions which then attain their mature structure by transformation of the meristematic tissue.

These distinctions are of some importance in considering the generalisation originally founded on animal development and known as the biogenetic law. That 'the ontogeny is a concise and compressed recapitulation of the phylogeny' is essentially a phyletic conception. It has been more or less criticised and challenged by some distinguished zoologists, and has always been difficult to apply to plants. If we avoid being prejudiced by zoological theory and results, we do not find that the characters of the embryos of plants have given the key to doubtful questions of phylogeny. What help do they give us, for instance, in the Algæ or the Vascular Cryptogams? The extension of the idea of recapitulation to the successively formed regions of the seedling plant requires critical examination; if admitted, it is at any rate something different from what the zoologist usually means by this. The facts—as shown, for instance, in a young fern-plant—are most interesting, but can perhaps be better looked at in another way. Development is accompanied by an increase in size of the successively formed leaves and portions of stem, and the process is often cumulative, going on more and more rapidly as the means increase until the adult proportions are attained. The same specific system of relations may thus find different expression in the developing plant as constructive materials accumulate. I do not want to imply that the question is merely a quantitative one; quality of material may be involved, or the explanation may lie still deeper. The point is that the progression is not a necessary one due to some recapitulative memory.

There are some other classes of facts, clearly cognate to normal individual development, that seem to require the causal explanation I may mention three: (1) Vegetatively produced plants (from bulbils, gemmæ, &c.) tend in their development to pass through stages in elaboration similar to young plants developing from a spore or zygote. The similarities are more striking the smaller the portion of material from which a start is made. (2) Branches may repeat the stages in ontogeny more or less completely also in relation to differences in the nutritive conditions. (3) In the course of continued development there may be a return to the simpler form and structure passed through on the way to the more complex. These cases of parallels to, or reversals of, the normal ontogenetic sequence suggest explanation on causal lines but are difficulties in the way of phyletic recapitulation; the first two cases can be included under this, while the third seems definitely antagonistic. On the whole it may be said that recapitulation cannot be accepted for plants without further evidence, and that preliminary inquiry disposes us to seek a deeper and more fruitful method of explaining the facts of development.

The development of most plant-individuals starts from a single cell, and when we compare mature forms of various grades of complexity the unicellular condition is also our usual starting point. What is not so generally recognised or emphasised is the importance of the filament as the primitive construction-form of most plants. I do not use the word 'primitive' in a phyletic sense, nor in the sense of an ideal form, but to indicate a real stage in independent progressions underlying many homologies of organisation. I cannot

develop this fully here, but wide comparison of independent lines of advance suggests that the main types of progress in complexity of the plant-body [10] have involved the elaboration of the single filament with apical growth and with subordinated 'branches.' It is generally recognised that various groups of Algæ show how a solid multicellular axis may come about not only by the further partition of the segments of the apical cell but by the congenital cortication of a central filament or the congenital condensation of the subordinated 'branches' on to the central axis. The Algæ further show the change from the dome-shaped apical cell of a filament to the sunken initial cell with two, three, or four sides. The central filament then only appears, if at all, as a subsequent differentiation in the tissue, and the segments serially cut off from the apical cell may or may not bear projecting hair-shoots or 'leaves.' The Algæ thus attain in independent lines a construction corresponding to that of the plant in Liverworts and Mosses. In the various parallel series of Bryophyta the filament is not only more or less evident in the ontogeny but may be regarded as the form underlying both thallus and shoot, between which on this view there is no fundamental distinction. The sporogonium also can be readily regarded as an elaborated filament. While the same interpretation of the fern-prothallus will readily be granted, to think of the fern-plant as the equivalent of an elaborated filament may appear far-fetched. So far from this being the case, I believe that it will be found helpful in understanding the essential morphology of the shoot. In a number of Vascular Cryptogams and Seed-plants, there is actually a filamentous juvenile stage, the suspensor, while the growth by a single apical cell is essentially the same in the fern as in the moss and some Algæ.

There follows from this a natural explanation of the growth by a single initial cell so commonly found in plants. The apical cell appears to be the one part of the massive plant-body (for instance, of *Laurencia*, a moss, or a fern) that persists as a filament; it is a filament one cell long. It may be replaced by a group of initial cells, as we see in some Algæ, Liverworts, and Pteridophyta, and this leads naturally to the small-celled meristems found in most Gymnosperms and Angiosperms. The filamentous condition is then wholly lost, though the system of relations, and especially the polarity, is maintained throughout all the changes in the apical meristem.

I feel confirmed in regarding the construction of the sporophyte in this fashion by the fact that it fits naturally with the conclusions resulting from the masterly comparative treatment of the embryology of the Vascular Cryptogams by Professor Bower.[11] These are (1) the primary importance of the longitudinal axis of the shoot, the position of the first root and the foot being variable; (2) the constancy of the position of the stem-apex near the centre of the epibasal half of the embryo; (3) the probability that embryos without suspensors have been derived from forms with suspensors, without any example of the converse change. These and other related facts seem to find their morphological explanation in the shoot of the sporophyte being the result of the elaboration of a filament.

The Construction of the Shoot.

The view to which we are thus led is that the uniaxial shoot is a complex whole, equivalent to the axial filament together with its congenitally associated subordinated 'branches.' This applies to the multicellular plant-bodies found in various independent lines of Algæ and Bryophyta, whether they have definite projecting appendages of the nature of leaves or not. The discarding of the distinction between thallus and shoot, which in practice has proved an unsatisfactory one, is no great loss. Even taking the word in the narrower sense of a stem with distinct leaves, the shoots in Algæ, Liverworts, and Mosses, though

[10] There are other lines of progression in complexity, the most important being the formation of a plant-body by the co-ordinated growth of a number of filaments. This line of advance is seen in many Algæ, in the larger Fungi, and in the Lichens. Though it raises morphological questions of great interest, it is here left out of consideration as not bearing directly on the organisation of the higher plants.

[11] *Land Flora*, chap. xlii.

admittedly independent developments, exhibit an essential correspondence amounting to a homology of organisation. The resemblances are not analogies, for it is doubtful whether the 'leaves' in the different cases correspond in function. The comparison of the shoot of the sporophyte of a Vascular Cryptogam with, for example, the shoot of the Moss seems equally justifiable. It is only forbidden by strict phyletic morphology, which for our purpose has no jurisdiction. The general agreement as regards the leaf-arrangement between the Ferns and the Bryophyta suggests that similar laws will be found to hold in the shoot of both gametophyte and sporophyte. Apart from plagiotropic shoots, there is a constructionally dorsiventral type of fern-rhizome. The leaves of this alternate as in the leafy Liverworts, while the radial type of fern corresponds to the moss-shoot. It is significant that the early leaves of radially constructed ferns usually exhibit a divergence of $\frac{1}{2}$ in the seedling, passing higher up the stem into more complicated arrangements, and the same is the case in mosses. I must not enter into questions of phyllotaxy, but may remark on the hopefulness of attacking it from the study of the simpler shoots of Algæ and Bryophyta rather than, as has usually been done, beginning with the Flowering Plants.

In some ferns (the striking example being *Ceratopteris*) the relation between the segmentation of the apical cell and leaf-production is as definite as in the moss, each segment giving rise to a leaf. This may hold more widely for ferns than is at present demonstrated, and the question deserves thorough re-investigation to ascertain the facts independently of any theoretical views. That the coincidence of the segmentation of the shoot expressed by the leaf arrangement and the segmentation of an apical cell is not a necessary one is, however, clearly shown in other ferns, and is obvious in the case of shoots with a small-celled meristem. The two segmentations appear to be determined by some deeper system of relations, which may also be manifested in a cœnocytic plant-body.

In the complication of the uniaxial shoot introduced by branching also there seems to be an advantage in a wide area of comparison. The question most often discussed concerns dichotomous and monopodial branching. If the details of development are to be taken into consideration, the term 'dichotomy' has usually been very loosely applied. Apparent dichotomy, the continuation of one shoot by two equally strong ones, is fairly common. But in most cases investigated in detail the branching seems to be really monopodial and the forking due to the equally strong development of a lateral branch close to the main apex, not to the division of the latter. In plants growing by a single initial cell almost the only case of strict dichotomy known is the classic one of *Dictyota*. The branching of the ferns has been the subject of numerous investigations, but there is a great lack of developmental data. Usually the branches stand in some definite relation to the leaves of the shoot, behind, to one side or on the leaf-base itself, the most interesting but least common case being when the branch is in an axillary position. When the mature shoot only is considered, it is possible to argue for the derivation of monopodial branching from dichotomy or the converse. Even the facts obtainable from the mature plant, however, point to the dichotomous branching being a modification of the monopodial, the opposite view appearing to land us in difficulties regarding the morphology of the main shoot.[12] It is unlikely that a dichotomy involving the division of the apical cell occurs in the fern-shoot, and comparison with the Bryophyta confirms the suspicion that the cases of dichotomy are only apparent.

In considering the construction of the shoot we are at present limited to comparison of the normal structure and development. The system of relations in the shoot of the fern, affecting in the first place the distribution of the leaves and secondly that of the branches, appears, however, to be of the same nature as in the independently evolved shoots of Bryophyta and Algæ. A morphological analysis based on the simpler examples may lead on to the experimental investigation of the common construction. The relation that exists between the general construction and the vascular anatomy offers a special and more

[12] The conclusion arrived at by Schoute, that the angular leaf in 'dichotomous' branching and the subtending leaf in monopodial branching are equivalent, supports this view. *Recueil des Travaux botaniques Néerlandais*, vol. xi.

immediately hopeful problem. Here also, in considering the fern, we are assisted by homologies of organisation in other Vascular Cryptogams and in the more complex Bryophyta, though the Algæ are of little help.

In few departments of botany has our knowledge increased so greatly and become so accurate as in that of vascular anatomy. The definiteness of the structures concerned and the fact that they have been almost as readily studied in fossil as in living plants has led to this. Not less important have been the clear concepts first of the bundle system and later of the stele under which the wealth of fact has been brought. Great progress has been made under the influence of phyletic morphology, and anatomy has adopted further conventions of its own and tended to treat the vascular system as if it had an almost independent existence in the plant. The chief method employed has been the comparative study of the mature regions, of necessity in the fossils and by choice in the case of existing plants. I do not, of course, mean to say that we are ignorant of the development of the vascular system, but the variety in it has not been adequately studied in the light of apical development. A gap in our knowledge usually comes between the apical meristem itself and the region with a developed vascular system. It is in this intermediate region that the real differentiation takes place and the arrangement of the first vascular tracts is then modified by unequal extension of the various parts. The apical differentiation requires separate study for each grade of complexity of the vascular system even in the same plant.

If we look at the vascular system, not as if it had an independent existence nor from the phyletic point of view, but as a differentiation taking place within the body of the individual plant, we can inquire as to the causal factors in the process [1] A deeper insight into the nature of the stele may be obtained by regarding it as the resultant of a number of factors, as part of the manifestation of the system of relations in development. The first step towards this is the critical consideration of normal developing plants, but so long as the causal influences in the developing substance of a plant remain unchanged the resulting vascular structure will remain constant. Our hope of advance lies in the study of cases where these influences are modified. Herein lies the value of abnormalities, of natural experiments, and the results of experimental interference. Possible influences that have at various times been suggested are functional stimuli, the inductive influence of the older pre-formed parts on the developing region, and formative stimuli of unknown nature proceeding from the developing region The functional stimuli do not come into play at the time of laying down the vascular tracts, though they may have importance in their maintenance later; the inductive influence of the anatomy of older regions is excluded in the first differentiation of the vascular system in an embryo; we are thus led to attach special importance to the detection of the action of formative stimuli proceeding from the young developing primordia. We have further to take external stimuli into account, though these must act by influencing the internal system of relations.

Time will not permit of reference to the scattered literature bearing on this subject, but it may make the reality of such formative stimuli a little clearer if I refer to some examples that have turned up in the course of my morphological work. In the case of the shoot, formative influences must act in the small apical region where we have the meristematic growing point with the primordia of the leaves. There is a presumption in favour of some sort of segmental construction of the meristem in relation to the leaves, whether this coincides with the cell-segmentation or not, and such a segmental construction is reflected in the vascular system. Can we in the first place distinguish any parts played by influences from the stem-apex and the developing leaves respectively? Unfortunately we know little or nothing of the anatomical relations in the rare cases of adventitious leaf-formation. We get a little insight into the respective influences of leaf and axis, however, when we compare shoots with well-developed leaves and those without leaves or with greatly reduced leaves; this may be done between distinct plants or between different regions of the

[1] An advantage that follows from this is that we get clear of the misleading metaphor of leaf-traces 'passing out,' &c.

same plant. It seems to emerge from such comparisons that, as regards the xylem at least, a central strand may be independent of influences from the leaves, while the latter may not only determine the leaf-traces connecting with the central strand, but may influence the periphery of this; the result is a cylinder of outer xylem continuous with the leaf-traces. This general conception is borne out by widely different plants, the correspondences between which are homologies of organisation. I may instance the stele of the Polytrichaceæ as analysed by Mr. and Mrs. Tansley, the stele of the rhizome and aerial shoots of the Psilotaceæ, of the Lycopods with larger or smaller leaves, and the stele of the ferns at various ages of the plant. The shoot of *Isoetes*, which is of the Lycopod type but has relatively large leaves, shows the composite nature of the stelar xylem particularly clearly and also suggests how the component influences are at work in the meristematic region of the stem bringing about the resultant structure.[14]

Owing to the small size of the shoot-apex it is difficult to induce deviations from the normal to show the respective parts played by the central axis and by the influences from the leaf-primordia. The reality of influences proceeding backwards from developing structures is better brought out when they may be present or absent, and for this lateral buds are of special interest. As a rule, the primary development of buds has proceeded far enough to determine the connecting vascular tracts, but in the case of the dormant axillary apices of *Botrychium* no influence has been exercised on the vascular structure of the main shoot. When, however, such a lateral apex is called into activity, it not only forms its own vascular system as it develops, but exerts an influence backwards through permanent tissue leading to the production of a 'branch-trace' connecting with the adaxial face of the subtending leaf-trace. In *Helminthostachys* a similar connection is established with the stele of the main stem, and the influence may extend to the whole periphery of the main stele, inducing a continued or secondary production of xylem both behind and before the place of insertion of the branch.

These constructions were in a sense called forth by experimental interference, since they occurred in plants the normal apical growth of which had been arrested. Plants of *Osmunda* are normally unbranched and no indication of dormant lateral apices have ever been detected. I tried on young plants of *Osmunda regalis* the experiment of injuring or destroying the apex of the shoot, with the result that in a number of them branching was induced. The vascular relations exhibited considerable variety, but in some clear cases the branch was developed in an axillary position with regard to a leaf-primordium[15] and its vascular connection was with the adaxial face of the subtending trace in the same fashion as in *Botrychium* and in some species of *Zygopteris*. The disturbance of the normal growth had apparently brought out (in more or less irregular form) the system of relations governing the position of development of lateral branches. The result showed the correspondence with what is the normal condition in some Zygopterideæ. It has been said from the phyletic side, and on the whole rightly, that experiment cannot reconstruct history. In the light of Dr. Kidston and Professor Gwynne-Vaughan's conclusions as to the derivation of the Osmundaceæ from a Zygopterid ancestry this induced branching of *Osmunda* might almost be cited as a partial exception to the statement.

These examples will suffice to indicate the justification for a change of attitude in the study of the vascular system. Looked at in this light, the stele appears not as a characteristic thing inherited as such, but as a complex resultant. The problem gains in interest, new questions (which are different from, though not antagonistic to, phyletic problems) can be put as to stelar structure, leaf-trace structure, the venation of leaves, &c. We see this if we glance at the progression in stelar structure that accompanies the development of the young fern.

[14] This is confirmed by the origin of a similarly differentiated 'stele' in relation to the insertion of the successively produced roots at the base of the plant of *Isoetes*.

[15] In another case the leaf primordium appeared to be replaced by an axillary branch—*cf.* the case of *Plagiogyria* described by Bower, *Annals of Botany*, vol. xxiv. p. 434.

The phyletic explanation has been recapitulation. We have found reason to criticise the adequacy of this as applied to external form, and the same line of criticism applies to the stelar progression. In this also the early stages may be hurried over or absent and, still more significant, the early type of stelar structure may recur, when the shoot has fallen upon evil days and approximated in size of stem and leaf-form to the seedling condition. From such points of view the vascular system offers problems in general or causal morphology not merely of great interest but with some possibility of solution. Thus the parallel progressions from protostely to a medullated monostele, and from protostely to solenostely and dictyostely may be treated as problems in the expansion and condensation of a stelar structure, which is itself the resultant of a system of influences. Such parallel progressions are before us within the ferns and also in other groups of Vascular Cryptogams.

One of the most remarkable of these (which also affords an example of a change in anatomical construction related to a change in the external conditions) is seen in the occurrence of a solenostele in the rhizome of *Selaginella Lyalli*. This has been explained by the relation of the aerial branch-systems to the rhizome being similar to that of the leaf to the creeping fern-stem. Professor Bower's suggestion [16] that in some way the different construction of the rhizome is due to the horizontal position acting as a 'stimulating cause' seems more in accordance with the facts for this *Selaginella*. At any rate, Mr. Speakman, working in my laboratory, has found that in *Selaginella Lyalli* all the lateral branches of the rhizome become polystelic, but, while this is maintained in the erect shoots, those which grow into horizontal branches become solenostelic by a fusion of the ring of separate steles first developed. Bruchman also found that polystelic shoots laid horizontally on the soil grow on into solenostelic rhizomes. This is so fundamentally different from the relation of the solenostelic and dictyostelic condition in ferns as to suggest that the homoplastic resemblance is here probably not a homology of organisation but due to different factors.

There is ground for suspecting the anatomical method when it stands by itself and also for very critically considering explanations of structural change on the ground of utility. When in the attainment of any more complex whole (as, for instance, in the origin of the shoot, the ovule or the flower), a new system of relations is established and the external developmental morphology of the primordia and their mutual relations are changed, this will be reflected in the vascular system. The resulting change in the latter may, however, be profound and not appear as a gradual modification of the preceding vascular system.

In the numerous theories of the construction of the shoot the evidence relied on has been partly comparison of mature form, partly, though to a less extent, development, partly the vascular anatomy, and largely phyletic series, most of which are very questionable. I must touch on this subject, but do not propose to involve myself in the details of particular theories. They can be broadly divided into those which regard the stem as in one way or another built up of potentially and phyletically independent segments or phyllons and those which regard the shoot as a phyletically pre-existing axis or stem from which the leaves have arisen by enation.

Considering the antagonism between these two lines of interpretation of the shoot that has held throughout the history of botany, I feel diffident in suggesting that there is much truth in both. In the light of general comparison the leaves cannot be looked on as mere enations from an unsegmented axis; nor, on the other hand, can the latter be regarded as composed of united leaf-bases. There seems an element of truth in the idea that the shoot can be analysed into segments composed partly of stem and partly of leaf; and another element of truth in the idea of a central column being clothed by some sort of pericaulome, though the form in which Celakovsky and Potonié have stated their theories and the evidence advanced makes their acceptance impossible. While the straightforwardness of the distinction between stem and leaf as put forward by Braun or in the strobilar theory is attractive and has apparent support in the apical development of the higher plants, it

[16] *Annals of Botany*, vol. xxv. p. 567.

seems impossible to overlook a segmental construction of the whole shoot in relation to the leaves.

The view of the general nature of the shoot to which we were led by a wide comparison including Algæ, Bryophyta, and Pteridophyta seems to enable us to understand in natural relation to one another the reality of the monopodial axis, its segmental construction, and the origin of the free portion of the leaves as outgrowths. The shoot is a new whole to be understood in the light of the method of elaboration of the single filament with subordinated appendages. As soon as the shoot is recognisable as an entity, the distinction can be drawn between these strictly subordinated appendages or 'leaves' and branches which repeat the whole construction. I cannot enter into the question of whether the fern-leaf is to be regarded as a transformed branch system, further than to state my opinion that the correspondence of the fern shoot as a whole with that of a Lycopod or a moss makes such a difference between their leaves unlikely.[17] The evidence in its support is drawn partly from an assumed origin of shoots from a hypothetical thalloid or pro-hepatic type and partly from vascular anatomy. The evidence on such questions from anatomy is, for reasons already given, perhaps the least satisfactory available, since the vascular tracts are established after the shoot as a whole has come into existence. They may to some extent reflect the original construction of the shoot, but may be largely independent of this.

If we test the opposed theories by their application to such a fern as *Ceratopteris* in the light of its embryology and apical development we find that the conception of leaf arising from leaf without the existence of a stem apex is not really supported by the facts. On the other hand, the segmentation of the shoot is evident throughout, owing to its coincidence with the apical segmentation. It is further most instructive to try to apply the various theories, whether phytonic or strobiloid, to the shoot of the moss with all its parallel correspondences to that of a higher plant.

Alternation of Generations.

The question of individual development led to the consideration of the morphology of the shoot. It also naturally leads us to glance again at the old problem of alternation of generations, for it is of profound interest to causal morphology that two very distinct individual forms should appear in the same life-cycle. The question thus raised concerns the nature of alternation, and is distinct from the historical question as to the origin of alternation, which for a time was regarded as constituting the whole problem. Any solution of the historical question depends on a knowledge of the lines of descent that have led to the various groups of the Algæ, Bryophyta, and Pteridophyta. We have seen how little prospect there is of this The various examples of alternation seem best regarded as homologies of organisation, independent manifestations of a similar condition. They are not less but more valuable on that account in studying the nature of alternation. To find the common ground from which the correspondences in this respect in the life-histories of Algæ, Bryophyta, and Pteridophyta result we might have to go very far back, possibly to the life-cycle of unicellular organisms. Even there the phenomena might be of independent origin and the homologies not homogenies. Were this the case we should have to contemplate an intercalation theory of the vegetative tissues not only for the sporophyte but for the gametophyte. This is necessarily mere speculation, but it helps us to realise, as Dr. Scott once said, how insoluble the problem really is.

I wish to dwell for a little on an aspect of it which is more open to attack, however difficult. This is the analysis of the phenomenon as we see it in the life-history of the fern with the object of arriving at some idea of the causal factors in the difference between the two generations. In one sense the fern-plant and the prothallus appear like two individuals; in another the two stages are like parts of the same individual. We seem almost forced to assume that

[17] The cases in Algæ where a shoot appears to result from the subordination of branches to an axis are of great interest, but require further elucidation themselves, while the other line of elaboration is clear. The difficult cases are mainly found in the Fucaceæ.

the specific substance of a fern can, as it were, exist in two anotropic modifications, the properties of which are revealed in the unlikeness of the two generations. Presented thus, alternation of generations becomes a special aspect of the problem of individual development.

This aspect of the problem is, indeed, apparent within what we naturally regard as individual development, whenever this is discontinuous. Thus in the moss we see within the limits of the sexual generation a marked discontinuous development leading to the formation of the leafy shoots upon the protonema. The change to the more complex type of plant-body is in some way determined in a single cell, which proceeds to develop in a new fashion. In some cases the stimulus of light of sufficient intensity appears to be effective, but we know nothing of the internal factors at work. The change, however, is not rigidly pre-determined, and it is of interest to find it at first reversible; the apical cell of the young bud may continue as a protonemal filament, though this rarely occurs in an older shoot. As another instance of discontinuous development, where also we have hints of an explanation, I may remind you of the inflorescences of *Veronica Chamædrys*. They differ in a number of respects from the main vegetative shoot of the plant, for instance in having spiral instead of decussate leaves and a different type of hair. When Klebs,[18] experimenting on the transformation of reproductive to vegetative shoots, succeeded with inflorescence cuttings of *Veronica*, the unknown modification in the growing point resulted in a change to the whole alternative system of relations, the growth continuing as a vegetative shoot with decussate leaves. These two examples suggest that from the causal point of view the alternation of shoots and the alternation of bionts again become parts of the same problem. There is no sharp line between continuous and discontinuous development, but the discontinuity makes it easier to analyse, and perhaps experimentally attack, some problems of development.

This last consideration applies to the normal alternation of the prothallus and fern-plant; the new start from the fertilised egg gives an impression of abrupt discontinuity greater than that in the origin of the inflorescence of *Veronica* or the moss-bud on the protonema, but the cases are not essentially different. It is true that the egg at fertilisation appears as a separate little mass of substance in the venter of the archegonium, but after fertilisation there is the closest physiological connection between the prothallus and embryo. In a sense the latter behaves as if it were a special bud or branch of the prothallus.

Some years ago I attempted to re-state from the ontogenetic side the question of the different development of the enclosed egg-cell from the free spore. I assumed the two germ-cells to be 'essentially alike, the different products of their development depending on the different conditions.' The development of the zygote in relation to the enclosing gametophyte was regarded as the important factor. Though the position taken up was somewhat crude, it was useful in eliciting statements on the subject from a number of botanists; this response being more valuable than the stimulus. The view advanced has been criticised in most helpful fashion by Professor V. H. Blackman,[19] who took the ontogenetic ground to which I was endeavouring to shift the problem. He considers the egg and spore to be different, in that 'one has received from the plant which bore it a tendency to become a sporophyte, the other a tendency to become a gametophyte.' He further extends the idea of correlation, as explaining the orderly development of an individual, to the whole life-cycle, and considers 'the various stages as united together by a *cyclical correlation*, one stage influencing the development of the other.'

Professor Blackman's view does not seem inconsistent with mine, but together with it gives a better statement of the position. My attempt was really towards an explanation of this cyclical correlation. When germ-cells are separated from the parent body, as in the case of the various spores of a Uredineous fungus, any differences in their powers must have been impressed on them previously and are manifested given the proper conditions. So far as this goes, it applies to the spore of the fern and in part to the egg. But the latter is in a different

[18] *Willkurliche Entwickelungsänderungen bei Pflanzen*, p. 69.
[19] *New Phytologist*, vol. viii. p. 207.

case from the spore. While peculiarities may already have been impressed upon it, a metabolic relation with the prothallus still continues, and the developing embryo may be further influenced by the latter. The essential of the view I advanced was the possible importance of this continued influence on the retained egg and embryo as giving the clue to its different development as compared with the free spore. The idea of the retention of the egg may be made a little clearer by distinguishing between effective and ineffective retention. The mere fact that an egg develops within an oogonium or archegonium only amounts to ineffective retention if mutual relations are not established between it and the gametophyte. Thus retention is ineffective in *Vaucheria* or *Œdogonium*, but it is not clear that it is so in *Coleochæte*. As regards the egg in the archegonium, however, there is evidence of mutual relations between the embryo and the prothallus. We see changes in the calyptra and in other parts of the prothallus following on the presence of a developing embryo. On the other hand, the symmetry of the normal embryo and the position of its primary members is determined by the relation to the prothallus, and not by the external influences of light, gravity, &c.

In trying to form any idea of the nature of the influences which result in the cyclical correlation between gametophyte and sporophyte in the normal life-history the deviations from the normal met with in apogamy and apospory are of assistance; they have an importance for causal morphology which was almost wholly overlooked when the problem of alternation was stated from the phyletic point of view. The first examples of apogamy and apospory described in the ferns were associated respectively with an absence of the sexual organs or of sexual reproduction and imperfection or absence of the sporangia. Later work has not diminished the possible importance of this sexual arrest or soral arrest in some cases, but has shown that the problem is by no means simple or direct. To properly discuss it would require the consideration of examples, not only of the transitions between plant and prothallus, but of the mix-up of tissues and members of the two generations. Our knowledge of these has increased greatly, but in most cases we are only acquainted with the phenomena without being in a position to understand them. Let me remind you of some types of apogamy: apogamous development of an ovum; direct apogamy as a constant character of the particular species or variety; direct apogamy with the occurrence of structures intermediate between gametophyte and sporophyte; induced apogamy in potentially normal prothalli; the development of isolated leaves, roots, ramenta, or sporangia upon a potentially normal prothallus. On the other hand, we have as manifestations of apospory: apospory as a regular characteristic of certain varieties; aposporous development from the attached leaves of young plants; induced apospory from the primary leaves of normal ferns; induced apospory by the arrest of spore production; and the occurrence of intermediate growths between sporophyte and gametophyte. Clearly no one formula will cover all these cases. The nuclear facts we now possess are of great interest, but do not give an explanation of the phenomena. The whole subject is a most promising one for critical and thorough experimental work, all that has yet been done in this direction being of the nature of prospecting.

Let us now assume that the normal alternation is due to cyclical correlation and try to analyse this a little further in the light of the facts of apogamy and apospory. The simplest cases of direct apogamy show a fern sporophyte continuous with the cushion of the prothallus, but with the relative position of its members the same as that of a plant developed from a fertilised egg. We are naturally inclined to think first of a change to the alternative system of relations and to remember that in the case of the normal embryo this takes place in a similar relation to the prothallus. When, however, we consider the strange cases of the perfect development of isolated members or tissues of the sporophyte on or in the prothallus, we seem forced to think further of special formative influences that are of the nature of substance rather than of a system of relations. We are confirmed in this by the fact that a number of cells may be simultaneously and collectively influenced, and that the influence may be reversed. This holds both for apogamy and apospory; in the latter when the prothalli develop upon leaves attached to the plant, it is difficult to see

how either external or internal influences equivalent to the usual relations can come into play. There is no nuclear change, at least of the nature of meiosis, and there seems nothing for it but to assume some material modification involving the change to the alternative condition of the specific substance expressed in the prothallus. The interest of these considerations, tentative as they must be, lies in the way in which they associate two explanations of development the influence of particular, unknown determining substances and the system of relations.

The whole question is fortunately not complicated with adaptation or any gradual origin of these deviations from the normal, and affords a particularly clear example of a problem in causal morphology. The perfect development of isolated members without the usual relation to the rest of the plant-body has an important regulative bearing on the current assumption that every stage in development is determined by the preceding stage. In this connection a most interesting parallel can be traced between the appearance of perfectly formed roots, ramenta, sporangia, and vascular tissue in induced apogamy and the development of bones, teeth, and hairs in dermoid cysts occurring in the human ovary or testis. The further study of the conditions of development in such abnormal cases may do much to enlighten us as to the factors concerned in the normal ontogeny.

The Seed and its Embryo.

So far the problems considered in illustration of the possibilities of a general causal morphology have been suggested by the fern. The nature of roots, of the sexual organs, and of sporangia might also be profitably looked into from the non-phyletic point of view. I shall instead step beyond the fern and glance very briefly at some problems of the seed and the embryo of the seed plants. The story of the great additions made of recent years to our knowledge of Palæozoic seeds is familiar to us all. It remains an open question, however, to what extent seed-plants are to be regarded as of polyphyletic origin and in particular to what extent their seeds are homogenous or are homologies of organisation. In spite of the wonderful widening of the field of comparison by the discovery and investigation of the Pteridosperms we have no compelling evidence of actual lines of descent showing steps in the origin of the seed. The presumption is now in favour of an origin of all or most seed-plants from ancient Filicales, the earlier view of their derivation from the Lycopodiales being weakened or abandoned. Since this phyletic problem lies, in part at least, within the period of geological history, direct evidence may be hoped for. But in the light of the progress of opinion on other large questions of descent we must remember the possibility of parallel evolutions, and may even suspend judgment as to whether the Cycadophyta have been derived from Pteridosperms or the Angiosperms from the Bennettitales. Comparisons of the organisation of the whole plant seem somewhat forced in both cases.

Looking at the facts broadly, we can hardly escape from a very strong suggestion of parallel development affecting a number of distinct groups. There is evidence of this in the case of heterospory, which is found at various points in the Lycopodiales, Filicales, and Equisetales, usually with no indication of its being a gradually acquired or an adaptive character. Heterospory is otherwise a darker problem than the origin of the seed-habit to which it was presumably the preface. The study of the variety in early seeds has suggested to experienced investigators that seeds also may be the result of independent development.[20]

From the point of view of causal morphology the seed appears to present problems parallel to those of the enclosure of the archegoniate sporophyte in the archegonium. The distinction made between effective and ineffective retention applies here also. The fact that the megaspores of some species of *Selaginella* germinate within the sporangium is not really an approach to the seed-habit; it is ineffective retention so far as results on either the spore-contents or the sporangium are concerned. In the development of the ovule, however, we find the embryo-sac constituting with the investing tissues a new

[20] *Cf.* Oliver and Salisbury, *Annals of Botany*, vol. xxv. p. 46.

whole. There is the same likelihood of effective correlations as in other portions of the individual plant in which a new relation is set up. Cases in which a new influence affects the meristematic structure of the plant—as, for instance, in galls or the root-tubercles of the Leguminosæ—seem to be parallel. They exhibit a differentiation of the investing tissue in relation to the enclosed portion and a suggestive similarity between the vascular arrangements in the root-tubercles and those in the more bulky ovules. The new construction in the galls cannot be regarded as in any sense adaptive or purposive on the part of the plant. We are forced to look at it causally, and perhaps such a mode of regarding the ovule and seed may prove to be the most helpful. On such a view the ovule would be a megaspore gall, later containing an embryo plant, and the problem would concern the system of relations existing between the parts as development proceeds Corresponding causes might independently result in corresponding constructions and the homologies between various seeds or the contents of various embryo sacs, though real, be homologies of organisation. This is consistent with the ideas we were led to entertain in the case of the shoot and of alternation of generations.

As a last example the embryo of the seed-plants may be referred to, though I must not venture far into the facts. While exhibiting differences, the embryos of various seed-plants present certain common features which contrast with the embryos of all spore plants, even the heterosporous forms. How far are these peculiarities causally connected with the seed-habit and to what extent are they marks of phyletic unity? We have seen grounds for suspecting that seeds are parallel developments What follows as to the construction of the embryo if we contemplate such independent origins from ancient Filicales? The suspensor has already been considered, and we can regard it as a persistent construction finding a use in some cases. In the embryos of the Filicales we see a very clearly marked type with a single relatively large cotyledon and a hypocotyledonary region between the shoot and root Without entering into the question of whether or not the Monocotyledons were derived from Dicotyledons, it seems clear on broad phyletic grounds that a single cotyledon condition lies behind the dicotyledonous or polycotyledonous condition. There is thus a presumption that there has been a change in the primary members of the embryo in this direction. It seems worth while to emphasise that, from a phyletic point of view, there is a real inconsistency between the origin of seed-plants from the Filicales and the relative primitiveness of dicotyly. Is it not possible that the conditions of early embryonic growth in the more or less cylindrical seed may have led to a more symmetrical construction of the embryo, and that the dicotyledonous or polycotyledonous condition, on the one hand, and the monocotyledonous condition with an apparently terminal cotyledon on the other, are two alternative expressions of this?[21] For reasons already given, the anatomy would follow the morphological change, and would have to be considered in the light of this, and not as affording safe evidence by itself.

Conclusion.

I have touched on a number of large questions, any one of which demanded separate treatment. My concern has not, however, been with them individually but as cognate problems justifying the deliberate adoption of a causal explanation as the aim of morphological work I have confined myself to problems bearing on the development and self-construction of the individual and tried to treat them so as to illustrate the causal attitude and possible lines of attack. Preliminary speculations on the questions considered can at best contain a germ of truth, and must be subsequently adjusted in the light of further facts. I have discussed these questions rather than the smaller modifications in individual development shown in metamorphosis, partly because the latter have of late years been treated from a causal point of view[22] and

[21] Recent observations of Coulter and Land on the embryo of *Agapanthus* appear to afford direct support to this view arrived at by quite a different line of comparison.—*Bot. Gaz.* vol. lvii. p. 509.

[22] *Cf.* especially, 'The Fundamental Problems of Present-day Plant Morphology,' *Science*, N.S. vol. xxii. p. 33, and other works by Goebel.

partly because I wished to consider questions that immediately affect us as working morphologists.

Did time allow, we should naturally be led to recognise the same change of attitude in biological science toward the problems of the origin of new forms. Questions of bud-variation and mutation are clearly akin to some of those considered, and the whole subject of genetics is a special attempt at a causal explanation of form and structure and the resulting functions. Close co-operation between the morphological analysis of the plant and the genetic analysis attained by the study of hybridisation is most desirable. It is especially desirable that both should deal with structure as well as with form, and in the light of individual development.

The causal factors which have determined and guided evolution can be naturally regarded as an extension of the same line of inquiry. The Darwinian theory, and especially the exposition of the principle of natural selection, was the greatest contribution ever made to the causal explanation of the organic world. Strangely enough, it led to a period of morphological work in which the causal aim was almost lost sight of Why evolution has taken place in certain directions and not in others is a problem to the solution of which causal morphology will contribute. The probability of orthogenesis both in the animal and vegetable kingdoms is again coming into prominence, however it is to be explained. When we consider the renewed activity in this field it is well to remember that, just as is the case with causal morphological work, we are picking up a broken thread in the botanical web. Lastly, as if summing up all our difficulties in one, we have the problem of adaptation. In attacking it we must realise that use and purpose have often been assumed rather than proved We may look to scientific ecological work to help us to estimate the usefulness or the selection value of various characters of the plant On the other hand, causal morphology may throw light on whether the 'adaptation' has not, in some cases at least, arisen before there was a 'use' for it. The hopeful sign in the recent study of these greater morphological problems is that the difficulties are being more intensely realised, and that rapid solutions are justly suspect The more the causal attitude is adopted in ordinary morphological work, the more hope there is of these larger questions being inductively studied rather than argued about

The causal aim is essentially different from the historical one, but there is no opposition between causal and phyletic morphology. They are rather mutually helpful, for there has been an evolution not of mature plants, but of specific substances exhibiting development. A deeper insight into the nature of ontogeny is thus bound to be of assistance to phyletic morphology, while the tested results of phyletic work afford most valuable guidance in general causal morphology, though this cannot accept any limitation to single lines of descent in its comparisons.

I have tried to bring before you the possibilities of causal morphology partly because the same attention has never been given to it in this country [23] as to other branches of botany and partly because if morphology be conceived in this broader spirit it need not be said that it has no practical bearing. I should not regard it as a serious disability were the study of purely scientific interest only, but this is not the case When, if ever, we penetrate into the secrets of organisation so far as to be able to modify the organism at will (and genetics has advanced in this direction), the practical possibilities become incalculable.

Probably all of us have reflected on what changes the war may bring to botanical work It is impossible to forecast this, but I should like to emphasise what my predecessor said in his Address last year as to pure science being the root from which applied science must spring Though results may seem far off, we must not slacken, but redouble our efforts towards the solution of the fundamental problems of the organism This can be done without any antagonism between pure and applied botany; indeed, there is every advantage

[23] One of the few exceptions to this is the excellent semi-popular lecture delivered to this section at Southport by Professor Farmer. ('On Stimulus and Mechanism as Factors in Organisation,' *New Phytologist*, vol. ii. p. 193.) Also Address to Section K at the Leicester Meeting (1907).

in conducting investigations on plants of economic importance. It would be well if every botanist made himself really familiar with some limited portion of applied botany, so as to be able to give useful assistance and advice at need. The stimulus to investigation would amply repay the time required. Even in continuing to devote ourselves to pure botany we cannot afford to waste time and energy in purposeless work. It is written in 'Alice in Wonderland' that 'no wise fish goes anywhere without a porpoise,' and this might hang as a text in every research laboratory.

A plant is a very mysterious and wonderful thing, and our business as botanists is to try to understand and explain it as a whole and to avoid being bound by any conventional views of the moment. We have to think of the plant as at once a physico-chemical mechanism and as a living being; to avoid either treating it as something essentially different from non-living matter or forcibly explaining it by the physics and chemistry of to-day. It is an advantage of the study of causal morphology that it requires us to keep the line between these two crudities, a line that may some day lead us to a causal explanation of the developing plant and the beginnings of a single science of botany.

In replying to a unanimous vote of thanks, the President said :—We meet under the immediate shadow of a great loss to British botany. Professor D. T. Gwynne-Vaughan, who was for many years Secretary and then Recorder of this Section, died on Saturday, September 4, and his funeral takes place this morning. There is no need for me, in speaking to botanists, to dwell on the value of Professor Gwynne-Vaughan's work. I could wish that Dr. Scott and Professor Bower, in whose laboratories his earlier work was done, and Dr. Kidston, with whom he has since so brilliantly collaborated, were here to speak. Alike in dealing with the anatomy of existing plants and with the fossil ferns, his work is characterised by rare originality combined with the greatest thoroughness. His papers on the anatomy of solenostelic ferns have exerted a deep influence on the methods and the modern development of plant-anatomy, while the series of memoirs on the fossil *Osmundaceæ* are a great contribution to palæobotany. Gwynne-Vaughan leaves a solid monument of achievement, but the loss of the work which a man with such genius for investigation might yet have done is an irreparable one. While in his published work Professor Gwynne-Vaughan confined himself to plant-anatomy, in which he was a master, he was a botanist of wide interests, in the field as well as in the laboratory, and a stimulating teacher. I cannot trust myself to speak of him as a colleague and as a friend.

In order to mark our sense of the great loss to botanical science caused by Professor Gwynne-Vaughan's premature death, and of our deep sympathy with Mrs. Gwynne-Vaughan, I move on behalf of the Committee that we adjourn the business of the Section for the time of the funeral service.

Professor F. E. Weiss seconded the motion for adjournment, which was carried unanimously, the members upstanding. The Section then adjourned until noon.

The following Papers were afterwards read :—

1. *On the Expression by Measurement of Specific Characters, with special reference to Mosses.* By Professor Julius MacLeod, *University of Ghent.*

Is it possible to describe and to identify an animal or a vegetable species by means of figures representing the value of the specific characters? I have tried to realise this by measuring 38 characters in about 90 species and 20 varieties of the genus *Carabus*. For each character I have determined the minimal, median, and maximal value in each species and variety. The figures, set in order in tables, enabled me to describe and to identify the species and varieties more accurately than by the usual methods of description. The war prevented me from finishing and publishing my work.

I tried to carry out similar work with plants, in the Cryptogamic Laboratory

of the University of Manchester. On the suggestion of Prof. Lang, I took mosses of the genus *Mnium*. I limited myself to the study of the leaves of the fertile stem of seven species of that genus, the material being obtained from the Barker Collection of British Mosses.

When we measure, for instance, the length of the successive leaves from the base to the summit of a fertile stem of a *Mnium*, we see that the length increases up to a maximum and then diminishes. Example:

Table α: *Mnium punctatum*, a stem with 10 leaves, in mm.

Leaves	1	2	3	4	5	6	7	8	9	10
Length	0.97	1.31	2.42	4.15	5.37	6.44	7.13	7.12	6.39	2.46

This curve represents the *period of growth of the character* under consideration along the axis; it is something quite different from a variation-curve properly so called. The seven species of *Mnium* agree in this respect with Table α.

In this paper I limit myself (except in one case) to that part of the stem which extends from the lowest leaf to the longest one. As the number of leaves is variable (between 8 and 56), I have divided this part of the stem into ten intervals, measuring the minimal, median, and maximal value of each character in the leaves of each interval. The figures of each given interval thus become comparable with the figures of the same interval in all the stems and species. Following this method, we find that the periods of all the measured characters of the seven species may be brought under three types:

1. The character increases from the base to the longest leaf and decreases beyond this. The curve in Table α is an example of this type.

2. The character reaches its maximum below the longest leaf, the position of the maximum being to a certain degree variable. Example: The breadth of the leaves of *Mnium cuspidatum* (Table β); the maximum here falls about the interval 4, the longest leaf being here the narrowest!

Table β (mm.).

Intervals	1	2	3	4	5	6	7	8	9	10
Breadth .	0 80	0 96	0 98	1.00	0 97	0 96	0 92	0.87	0.79	0.71

3. The character reaches its highest value in the leaves which are above the longest leaf. Example: In *Mnium punctatum*, the nerve is *short* and never reaches the summit of the leaf in the three first intervals; in the intervals 4–10 it grows *longer* and approaches the summit more and more; in the leaves above the longest one in all the specimens the nerve reaches the summit.

These three types are more or less variable along different lines. The increase of a character from one interval to the following is more or less rapid. In several cases the increase is rapid in the first intervals and slower further on. Example: The number of cells in the transverse direction at the place of the greatest breadth in *Mnium cuspidatum* (Table γ):

Table γ.

Intervals	1	2	3	4	5	6	7	8	9	10
Cells .	59	74	81	82	84	86	85	86	85	80

Some characters have the value 0, *i.e.*, they do not exist in the first intervals; they show their period in the following intervals.

The knowledge of the period of a certain number of characters *a*, *b*, *c*, ... enables us to make clear the variability of the leaves of the same stem. The value of the characters *a*, *b*, *c*. . . . . of each leaf depends on the position of the leaf. In other words, a leaf which belongs to the n^{th} interval will have the values of the curves of the characters *a*, *b*, *c*, ... in that interval. *As each character has its own independent curve*, and as *much diversity exists among the curves*, the result is a practically unlimited number of combinations. Each leaf shows such a combination. It is impossible to analyse this form of variability by any other method.

By the knowledge of the periods and by the division of the axis into a certain number of intervals (I have managed with ten), we are enabled to study the correlation which exists or may exist:

(*a*) **Between the characters of the leaves of one stem;**

(*b*) Between the leaves of several stems of the same species (by comparing the leaves which belong to the same interval in all the stems);
(*c*) Between the leaves of several species of the same genus (same method as for *b*).

We are also enabled to study more accurately the ordinary variability of a given character among individuals of the same species, by comparing the leaves of the successive intervals 1, 2, ... *n* of several specimens.

The *description of a species*, according to my method, consists of a certain number of tables giving the period of each character, the figures being based as far as possible on specimens from several localities. I have studied *Mnium cuspidatum*, *M. hornum*, *M. punctatum*, *M. rostratum*, *M. serratum*, *M. subglobosum*, *M. undulatum*; for each species the following characters were taken: Length, breadth, breadth at the base, number of cells and breadth of the cells at the place of the greatest breadth, breadth of the border and number of cells of the border at the same place, number of teeth at the border and on the nerve, length of the nerve (reaching the summit or not), tooth at the summit of the leaf (present or absent), total number of leaves of the fertile stem.

To make the *identification of a given specimen* easier, we may use tables giving the minimal and maximal values of each character for the leaves of the 10th interval (longest leaves) only. The following Tables are of this nature:—

Table δ (mm.).
Length, minimum.

Serratum	2.91
Cuspidatum	3.73
Subglobosum	4.45
Rostratum	4.90
Hornum	5·42
Punctatum	5 75
Undulatum	6.93

Table ε (mm.).
Length, maximum.

Serratum	4.53
Cuspidatum	4.68
Subglobosum	7.06
Hornum	7.49
Rostratum	8.32
Punctatum	9.21
Undulatum	11.61

Table ζ (mm.).
Breadth, minimum.

Serratum	0.72
Hornum	0 87
Cuspidatum	1.29
Rostratum	1.80
Undulatum	1.82
Punctatum	2.77
Subglobosum	3.05

Table η (mm.).
Breadth, maximum.

Serratum	1.27
Hornum	1.38
Cuspidatum	1.88
Undulatum	2 35
Rostratum	3.19
Subglobosum	5.50
Punctatum	6.48

For example, on using the Tables δ–η, we take the longest leaf of a fertile stem and obtain the following measurements: Length 5.64 mm, breadth 2.15 mm. Let us try to identify the species by means of the tables: δ excludes *undulatum* (and perhaps *punctatum*); ε excludes *serratum* and *cuspidatum*; ζ excludes *punctatum* and *subglobosum*; η excludes *serratum*, *cuspidatum* (both already excluded), and *hornum*. The stem thus belongs to the species *rostratum*.

In this example it was possible to find the name by two characters; of course, we shall often be compelled to make use of three or more characters. As we have at our disposal a dozen of characters, we may hope that the identification of a given specimen will be always possible, even if the species to be considered were more numerous, the specific tables of the periods allowing verification.

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2. *The Aptian Flora of Britain: Early Angiosperms and their Contemporaries.* By Dr. Marie C. Stopes.

The so-called 'Lower Greensand' deposits of this country are of Aptian age, and represent the upper division of the *Eocretaceous* according to the recent classification of Haug. From these deposits the plants hitherto known

—notably *Bennettites Gibsonianus* Will. and *Cupressinoxylon vectense* Barber—have been so few that it has been impossible to speak of a Lower Greensand 'flora.' It has been generally assumed that both the climate, and the animals and plants then living were the same as those of the preceding Wealden.

As a result of recent work the author has now brought together a flora consisting of 45 species, containing 9 Cycadophyta, 27 Conifers, and 5 Angiosperms. Most of these are represented by petrifactions of the cellular anatomy, and many are very beautifully preserved.

Some of the forms have structures of botanical interest, while others are of value as indicators of the climate of the epoch, of which nothing was previously known. It is interesting to find evidence of a change of climatic conditions about this time, so that the cooler weather and well-marked seasons of the Lower Greensand afford a great contrast to the 'tropical climate' of the Wealden of Southern England.

Among the plants of botanical interest may be mentioned a new genus of *Cycadophyta* with curious wood structure; a new species of *Protopiceoxylon*; the leaf anatomy of a true *Sequoia*; several species of *Pityoxylon* with well-developed ray-tracheids; and several Dicotyledons. It should be remembered that these are all contemporaneous with the type species of *Bennettites*. The Angiosperms are the oldest found in Northern Europe, and the oldest of which the anatomy is known. They are all woody; two of them, at least, must have had tall timber trunks. In some of them the minute details are particularly beautifully petrified, and show a very high degree of organisation. Like the Conifers, they show seasonal growth. They represent a dry—possibly fairly high—land vegetation.

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3. *The Application of Science to the Cotton Industry.*

By W. Lawrence Balls, *M.A.*

The cotton industry does not consist of spinning and manufacture alone, but of cotton-growing as well. Co-operation between the spinner and the grower is desirable, and for this the scientists should be able to provide a language common to both.

Advances may be made in the organisation of the industry as a whole by more exact knowledge of the available supplies of raw material. Science could be applied to steady the market by producing precise crop-reports and crop-forecasts, which might even be issued daily, like weather-charts. The seed-supply might also be arranged so that production should meet the demand foreseen by the mills.

In studying the cotton-crop it is now an easy matter to follow the life-history of experimental plots and areas in minute detail from day to day throughout the season. The effects of weather, soil, &c., can thus be exactly traced. Cotton-growing need not be an empirical art.

The introduction of pure strains of cotton has already thrown some light on the spinning properties of raw cotton. Pure-strain lint will spin well, even when the sample is such as the expert grader would condemn as worthless It is more uniform. If thoroughly studied in the mill, this peculiar behaviour of pure strains will lead to better knowledge of the spinning properties of cotton.

Such knowledge of the causes which determine the properties of any given sample of cotton is not merely desirable, but is necessary, if co-operation is to be effected between the grower and the spinner. The latter must be able to state what kind of cotton he needs, using language which the grower can understand. At present the sole reliable test for the value of a sample of cotton is to spin yarn from it, which the grower obviously cannot do.

With such knowledge and co-operation, the strength of the yarn might be increased very appreciably.

THURSDAY, SEPTEMBER 9.

The following Papers were read :—

1. *Preliminary Observations on the Nature and Distribution of the Statolith Apparatus in Plants.* *By* Miss T. L. PRANKERD, *B.Sc.*

The term 'statolith' is used to designate a body free to fall within the cell (the statocyte) which contains it.

Liverworts show a response to gravity in the disposition of their reproductive organs, which is most marked in the gametophores, *e.g.*, *Lunularia cruciata*, *Corsinia marchantioides*, *Plagiochasma italicum*, *Reboulia hemispherica*, *Fegatella conica*; and the statolith apparatus shows a striking correspondence in (1) locality, (2) time of appearance, and (3) degree of development.

Ferns develop a statolith apparatus at the physical apex of young fronds which show negative geotropism. The case of *Ophioglossum vulgatum*.

Certain Monocotyledons which do not ordinarily produce starch nevertheless develop statoliths, *e.g.*, the foliage leaves of Narcissus.

Seedlings show statoliths in the developing root and stem, even when no starch is contained in the resting plumule or radicle, and when no trophic starch is produced by these young organs.

The petioles of many foliage leaves possess statoliths which do not disappear when all the trophic starch is dissolved. Special interest attaching to the case of *Sagittaria sagittifolia*.

Statoliths seem to be absent from very delicate organs (*e g.*, some seedlings, *Anthoceros* sporophyte), from organs in which a geotatic position is of no advantage (*e.g.*, vegetative thalli), and from organs where curvature is impossible.

The present investigation indicates that—

Statoliths are often chloroplasts, which may be termed 'chlorostatoliths'; *e.g.*, *Lunularia*, *Ophioglossum*, *Myriophyllum Proserpinacoides*.

Statocytes may be specialised (1) in shape (as in *Polygonum persicaria*), (2) in the possession of larger nuclei than the cells of the surrounding tissue (as in *Polygonum amphibium*), and (3) in the behaviour of the nucleus (as in some Pteridophytes).

The statolith apparatus consists of the whole system of statocytes, which, in Angiosperms, are usually to be found abaxially to the phloem, but may occur singly or in patches in the ground tissue ('diffused type'), or may themselves form a tissue ('complete type'), for which the term 'statenchyma' has been suggested.

Modifications and transitional forms occur. The author considers the statolith an intensive mechanism, the simplest form of statocyte being the living cell, which, passing through transitional stages, reaches its highest expression in the cell containing relatively heavy bodies differentiated both in size and mobility.

2. *On the Liquid Pressure Theory of the Circulation of Sap in Plants.* *By* Dr. SARAH M. BAKER.

The two main theories at present current to explain the ascent of sap in trees are the cohesion theory of Dixon and the vitalistic theory upheld by Ewart and Janse.

A new method of calculating the cohesion of liquids from the latent heat, by a modification of Stefan's equation, shows that cohesion varies inversely with the absolute temperature. Dixon and Joly's experimental demonstration of large cohesive forces in the interior of liquids depends, therefore, upon the increased cohesion caused by lowering the temperature of an enclosed liquid, and cannot be applied to liquids at constant temperature.

On the other hand, the experiments of Strasburger and Dixon on the ascent of sap through dead wood have shown that the postulate of the co-operation of parenchymatous tissues in the stem is untenable.

The present theory is founded primarily upon the ecological evidence that

high trees only grow where there is a possibility of the access of water-vapour to their roots. When either drought or low temperature or an excess of liquid water decreases the vapour supply beyond a certain limit, trees disappear, while the plants occupying these habitats show marked xeromorphy.

The theory assumes that the root is divided into two regions: (*a*) the root hair zone, specialised for salt absorption, which is permeable to liquid water or 'hydropermeable'; and (*b*) the growing region of the root-tip, specialised for water absorption, which is impermeable to liquids but permeable to water-vapour. Both assumptions are justified by experiment.

The membrane of the root-tip has been called 'aeropermeable' because it is permeable to gases but not liquids, and its activities are responsible for the pumping efficiency of the root. A membrane with these properties has not been artificially prepared. But it is possible to deduce its qualities mathematically by comparison with the known semipermeable membranes. Its most important function is to demonstrate the pressure of the substance it encloses, *i.e.*, liquid water. The total internal pressure of liquid water has been calculated by Van der Waals and Stefan, and reaches magnitudes of 20,000 atmospheres at low temperatures. Because this pressure is normally nullified by cohesion it can only become available when, by a valvular device of molecular dimensions, the liquid is allowed to pass in one direction and not the other. This device is afforded by the aeropermeable membrane. Through it liquid pressure may be generated by a chemical reaction (*e.g.*, respiration) which produces water at the expense of a gas, or by a physical change of state producing liquid from the condensation of vapour.

The latter mechanism, according to this theory, is responsible for root-pressure. The condensation of vapour is effected by the lowering of vapour-pressure caused by the osmotic substances in the cell solution. This is sufficient to counteract the increase of vapour-pressure caused by internal hydrostatic pressure.

The condensation involves a direct conversion of energy and 90 per cent. of the latent heat evolved in the process (580 cals. per gramme at 20°) may, theoretically, be converted into liquid pressure. This energy is sufficient to raise two hundred times the weight of the condensed water to 100 metres, allowing that the frictional resistance to flow in the xylem is five times the hydrostatic head The ultimate source of energy is the combined action of capillarity imbibition and solar heat on soil particles of different sizes, which produces a slight supersaturation in the interstices of the soil.

The second function of the root—the absorption of nutrient salts—is supposed to be effected by the alternate extrusion and absorption of an acidic solvent through the root hairs. The conflicting evidence on the presence of this acid excretion is reconciled by the recognition of the aeropermeable membrane in the root-tip.

Further, it is suggested that the movement of water in plants is a circulation, in which the whole upward current travels in the xylem and the whole downward current in the phloem, while the medullary rays serve to maintain the continuity at every level.

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3. *The Effect of Temperature on the Permeability of Protoplasm to Water.* *By* Dr. E. Marion Delf.

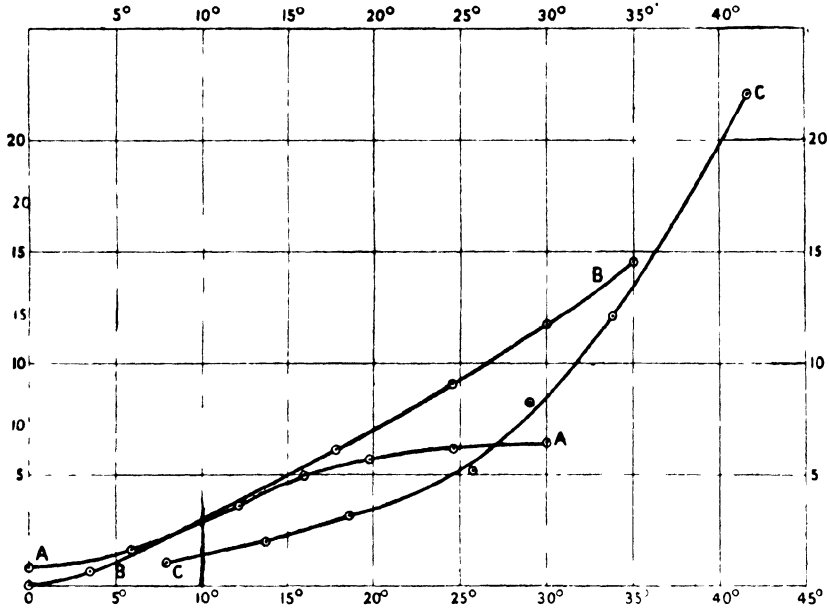
By the use of the optical lever and an apparatus designed by Dr. F. F. Blackman it has been possible to observe minutely the gradual contraction of a plant tissue undergoing plasmolysis, and thus to determine the rate at which water passes out through the protoplasm by exosmosis. By making these observations at different temperatures, the effect of temperature on the permeability of protoplasm has been investigated.

The behaviour of plant tissue during plasmolysis depends considerably upon the strength of solution employed. With dilute solutions of cane sugar and dandelion scapes, the course of plasmolysis at any temperature is represented approximately by a logarithmic curve. Curves of this type were obtained at different temperatures ranging from 8° to 42° C., and the rate of passage of

water through the protoplast was obtained by measuring the tangent of the slope of the appropriate curve at several specified stages of plasmolysis. For comparing the rates of permeation at different temperatures, values obtained *from corresponding stages* in plasmolysis were alone used. Thus for dandelion scapes at mid-plasmolysis, the rates were :—

1	2	3	5	8	12 and 22 at
8°	14°	19°	26°	29°	34° and 42° C.

The temperature effect thus seen is much greater than that observed by van Rysselberghe, who by measuring the contraction of pith cylinders in plasmolysing solutions at different temperatures found comparatively little difference



Curves showing the effect of temperature on permeability of protoplasm.

AA. Pith experiments of van Rysselberghe.
BB. *Pilobolus* (sporangiophores).
CC. Dandelion (scape of inflorescence).

in the rates above 20° C. It is comparable with the results of Lepeschkin, who observed the effect of temperature on the rate of secretion of water-drops by the sporangiophores of *Pilobolus*, and thence deduced the effect on the permeability of protoplasm. These results are expressed graphically in the curves A (van Rysselberghe) and B (Lepeschkin); the curve C is derived from the figures quoted above for dandelion scapes.

From the curve of rates of permeation for dandelion, the following coefficients of acceleration of rate for a rise of temperature of 10° C. can be calculated :

10° to 20° C.	2·5
20° to 30° C.	2·5
30° to 40° C.	2·3

From Lepeschkin's data, the corresponding coefficients for these temperature intervals are found to be 2·2, 1·7, and 2·1 respectively. Van Rysselberghe's

curve does not represent comparable rates at different temperatures, since he made his measurements not at specified stages of plasmolysis but after a fixed time interval (two hours), when the pieces at low temperatures were at an early stage, while those at high temperatures were completely plasmolysed.

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4. *The Respiration of Partly-dried Plant Organs.* By A. MALINS SMITH.

Plant-organs, such as the leaves of the Snowdrop, stem-tips of *Tropæolum*, and young stems of *Asparagus*, were deprived of varying proportions of the water they contained by drying in a vacuum desiccator at a pressure of about half an atmosphere. In the partly dried condition their CO_2 output was measured by passing over them a stream of CO_2 free air and analysing the outgoing air by means of baryta in Pettenkofer tubes. Confirmatory experiments were made with plants dried at ordinary atmosphere pressure. The results were as follows:—

(1) When deprived of from $\frac{1}{3}$ to $\frac{1}{2}$ of the total water contained, the respiration of the dried plants was increased over that of normal plants.

This occurred in the case of stems of *Tropæolum*, stems and roots of Bean seedlings, and in the leaves of the Snowdrop. A very slight increase was found in stems of *Sempervivum*.

No increase was found in young stems of Pæony or in young stems of *Asparagus*.

On account of the time taken in drying, the first phase of normal respiration was completed before the plants were tested, and all the results apply to the second phase, called by Dr. F. F. Blackman the 'protoplasmic' respiration, when the reserve food supply of the organs has practically disappeared.

(2) Experiments to find whether this increased effect was a reversible one have not yet been conclusive, but so far there is no evidence for reversibility.

(3) A thorough investigation of the course of respiration with varying amounts of water lost, a fresh lot of plants being used for each test, showed that the resulting respiration could be divided into three phases:—

(i) On removing small percentages of water, from 0 to about 30 per cent. of the water originally present, the respiration gradually increased in proportion to the amount of water removed.

(ii) In the second phase the respiration remained steady at the increased level. The length of this phase varied, lasting from 25 or 30 per cent. to 50 or 60 per cent. loss of water.

(iii) From 50 to 60 per cent. loss up to complete dryness the respiration decreased again proportionally to the amount of water lost. The curve of results indicated that in all material the plants continued to give out some CO_2 as long as any water was left in the tissues.

There were minor differences between the results in the two principal cases investigated, namely Snowdrop leaves and *Tropæolum* stems, but in each case the three phases were clearly marked.

The meaning of the increased 'protoplasmic' respiration in partly dried material is obscure. Harden and Paine have shown that the activity of glycogenase in the autofermentation of yeast is increased by simple drying. Possibly the increased respiration shown in these experiments may be due to the increased activity of one or more enzymes. Further experiment on that part of the curve of CO_2 output relating to plant organs which are almost perfectly dry may throw some light on the question of residual vitality, and may perhaps have interesting connections with the condition of air-dry seeds.

Demonstrations were given in the Botanical Laboratories of the University by Dr. Sarah M. Baker, Professor W. B. Bottomley, Professor F. O. Bower, Professor D. Ellis, Professor Julius MacLeod, Professor F. W. Oliver, Professor T. G. B. Osborn, Mrs. Edith M. Osborn, and Dr. Marie C. Stopes in connection with their papers: also by Miss N. Bancroft (*Petiole of* Zygopteris

cylindrica); Miss T. L. Prankerd (*Simplified Method for Estimating the Strength of Wheat*); Mr. W. Robinson (*Germ-tubes of* Uredineæ *and Abnormal Spermogonia*); Mrs. M. G. Thoday (*Seeds of* Gnetumgnemon); Dr. D. Thoday (*Micro-eudiometer for measuring gas evolved by assimilating water-plants*); Mr. H. B. Speakman (*Branching of Rhizome in* Selaginella Lyallii), and Professor F. E. Weiss.

FRIDAY, SEPTEMBER 10.

The following Papers were read :—

1. *The Phyletic Arrangement of the Filicales, with special regard to the Dipterids and Pterideæ.* *By* Professor F. O. Bower, *F.R.S.*

2. *Further Deductions from the Figures of Rarity of the Ceylon Flora.* *By* Dr. J. C. Willis.

In a recent paper the author endeavoured to prove that the commonness of a species depends upon its age (in the country concerned) and that local endemic species are simply new species in the earlier stages of spreading. Accepting these conclusions, we may go on to deduce many others from the figures of rarity of the Ceylon flora.

From the fact that the species of wide distribution (which must be the oldest) increase in number up the scale of commonness, whilst the endemics (the youngest) increase downwards, and the Ceylon-Peninsular-Indian species are comparatively evenly distributed along it, the conclusion is drawn that tables like these represent three stages in the history of a group of species, the distribution of the 'wides' being the latest.

Tables, &c., were given from which it is concluded (1) that there is no evidence that any species are dying out; (2) that the dry zone of Ceylon was on the whole peopled with plants a good deal later than the wet, and received its flora in two ways, either directly from the dry zone of India, or from the wet zone of Ceylon, the plants entering by the latter route becoming more quickly common; and (3) that there is little to choose in average age in Ceylon between (*a*) herbs and (*b*) shrubs and trees, though there is evidence to show that the Monocotyledonous trees and shrubs are very old, and that the Gamopetalæ as a whole are older in Ceylon than the Archichlamydeæ.

3. *The Periodicity, due to Coppicing, exhibited by the Ground Flora of Oak-Hornbeam Woods on Clays and Loams.* *By* Dr. E. J. Salisbury.

Before the shrub layer is coppiced two phases can be recognised, viz., (1) The Light Phase, extending from the leaf-fall in autumn to leaf-expansion in spring, and (2) the Shade Phase, from about the middle of spring to autumn. During the former period from 40 to 60 per cent. of the total light reaches the ground vegetation, whilst during the latter from 5 to under 1 per cent. only penetrates. It is probably the degree of shading during the Light Phase which largely determines the amount of ground flora. (The light intensities were obtained by means of an actinometer. The intensity outside the wood at the time of the test being taken as the standard.) The alternations between 'Light' and 'Shade' phases also correspond to alternations in the degree of exposure. The ground-flora of the uncoppiced wood consists almost exclusively of perennial herbs which possess storage organs. These produce their foliage very early in the spring. Thus most of their assimilation is carried on during the 'Light' phase. With a few exceptions (*Mercurialis*, *Galeobdolon*) the vegetative periods of the members of the shade-flora end soon after the 'Shade' phase begins.

After the undergrowth is coppiced there is a great increase in the number

of species, as also in the total amount of vegetation, occupying the areas formerly shaded. The invading species are mostly those which, before coppicing, were confined to the margin of the wood and the edges of the paths. Thus the total number of species in the wood as a whole remains relatively constant. The chief exceptions to this generalisation are plants with a good dispersal mechanism, chiefly weeds, which occupy neighbouring areas of cultivation. The total number of species increases for several years, but the maximum development of the ground-flora is reached in the second or third year after coppicing. The coppiced wood has a higher acidity and lower water-content than the uncoppiced. Plants tolerating high acidity are often abundant, and correlated with the diminished shelter rosette plants are frequent. As the coppice-stools sprout, the shelter and shade become gradually re-established. The light-demanding flora forms a reticulum in which the stools and shade-loving species occupy the meshes.

Finally the light-demanding species only survive by the paths and along the edge of the wood. If the coppicing period be short, a few may survive in a non-flowering condition till the undergrowth is again cut.

Before coppicing, the later flowering species often do not bloom, but in the second year after coppicing they usually flower profusely (*Galeobdolon*, *Ajuga*, *Conopodium*). Individuals in the coppiced part of a wood tend to come into bloom earlier than those of the same species in the uncoppiced part. This is probably related to illumination and the temperature of the soil. The latter in the spring is usually higher in the coppiced than in the uncoppiced areas. Frequent coppicing appears to prevent regeneration of the shrub layer from seedlings.

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4. *Observations on the Morphology of* Selaginella uliginosa *Spring.* *By* Professor T. G. B. Osborn.

Selaginella uliginosa, a species belonging to the subgenus *Homœophyllum*, and occurring in Eastern Australia, is remarkable for the well-developed rhizome on which erect aerial shoots are borne laterally, ·25-2·5 cms. apart. The aerial shoots have decussate leaves and two rows of lateral branches, the latter developed in the plane of the long axis of the rhizome and not in leaf axils. The cones, which are produced upon the lateral branches or terminate the main axis, closely resemble the sterile portions of the shoots. A '*Selago* condition' is common, the aerial stem surviving more than one season, when the axis of the cone continues growth, producing more vegetative leaves before a second reproductive phase is entered upon. The sporophylls show a well-developed 'dorsal flap.'

The rhizome is solenostelic with ramular gaps. The first break in the xylem ring is formed by the departure of the rhizophoric trace from the dorsal margin of the gap. Next the branch trace leaves the ventral margin, the gap being prolonged forward, but not overlapping. The branch trace may divide immediately, forming either two aerial shoots, or the basiscopic portion may form a rhizomic branch.

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5. *Preliminary Observations on an Australian* Zygopteris. *By* Mrs. Edith M. Osborn.

The specimen described was found about four years ago *in situ* in shales and tuffaceous agglomerates in the bed of the Manilla River, 12 miles west of Barraba, New South Wales. The shales contain abundant *Lepidodendron australe* and narrow beds of radiolarian chert and limestone. They have been named by Mr. W. N. Benson, of Sydney University, to whom I am indebted for information concerning the horizon, 'the Barraba series,' and are considered by him to be of Upper Devonian age. They are directly overlain by beds containing a Lower Carboniferous marine fauna. It is impossible as yet to draw a sharp line of distinction between the two series. The *Zygopteris* occurred near the transition zone, but below it rather than above, so that it may be considered of Upper Devonian age. The specimen consisted of three closely associated stems, each

surrounded by roots and petiolar bases, rather suggesting a habit similar to that of *Todea barbara*.

The lower face of the fossil was of an irregular elliptical shape 7 cms. long by 4·3 cms. wide. Each stele on this face showed three or four petioles.

The upper face, which was much larger, 7 cms. by 8 cms., had been fractured obliquely, so that the greatest length of the specimens on one side was approximately 8 cms., while on the other side it was only 3 cms. In this length of stem each stele gave rise to two leaf-traces, so that the departure of six leaf-traces can be seen in the whole block.

The sections which have been cut show excellent preservation of the tissues. Both stems and leaves bear external glands or hairs. The stem stele is of a five-rayed star-shape with blunt points, the pith, which contains tracheids, being also star-shaped. The structure is in the main of the *Ankyropteris Grayi* type with less acute points, but with no axillary branches. Leaf-traces leave the stele in the same order and manner as described for *A. Grayi*. As each departs it is of a triangular shape with rounded angles, the apex of the triangle being the point of attachment to the stem. This bundle soon becomes flattened tangentially, so that before it leaves the cortex it has the appearance of a flattened ring, slightly curved, with the convexity of the curve on the adaxial side. As the trace passes outwards it becomes still more flattened and tangentially elongate, until when a little above the base of the petiole it appears as a long band-shaped xylem mass, without curvature, rather constricted in the middle, and with a peripheral loop containing parenchyma and small tracheids at each end. Thus the petiolar structure is of the Clepsydropsoid type. None of the petioles are continued high enough to show detached pinna traces, though they are high enough to show that the simple type of petiole structure is maintained and it does not pass into a more complicated state, as in *Diplolabis* and *Ankyropteris*. Preparations for the departure of pinna traces are seen in some petioles. The traces, which are in two series, one from each peripheral loop, consist of a ring of tracheids with parenchyma in the centre, very like those figured for *Clepsydropsis antiqua*.

The combination of the outstanding features of this fossil—the *A. Grayi* type of stele, the absence of axillary branches, and the simple Clepsydropsoid petiole—defines it clearly as a new type and an interesting addition to the already known members of the Zygopterideæ.

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6. *The Formation of Auximones from Nitrogenous Organic Substances.* *By* Professor W. B. Bottomley, *M.A.*

The bacterial scum formed on crude nitrifying culture solutions in the presence of auximones has provided a method for investigating the occurrence of these substances.

It has been found that auximones are formed during the germination of seeds, and enable the young embryo to utilise the food material present in the seed. The phosphotungstic fraction from dry wheat, pea and maize seeds gave no scum. A similar fraction from seeds which had germinated for two days yielded a thick scum. Excised young embryos of wheat and maize failed to grow in Detmer's culture solution, but flourished in culture solution containing one part in three millions of auximone.

Auximones are formed during the humification of nitrogenous organic matter, and the amount of auximone present depends on the extent of humification. Fresh stable manure, two-year-old rotted manure, and bacterised peat were fractionised in the usual manner. The minimum quantity of these fractions necessary to produce a scum were as follows:

Fresh manure	extract from 50 grms.
Rotted manure	,, ,, 10 grms.
Bacterised peat	,, ,, 0·2 grms.

The relative proportion of auximone is therefore 1 : 5 : 250. Hence the amount of auximones increases with the progressive humification of the organic matter.

Experiments on *Lemna minor* growing in Detmer's culture solution show that the purer auximone silver fraction is more effective on growth than the cruder phosphotungstic fraction. Six glass dishes, each containing thirty *Lemna* plants, were arranged in three series of two dishes each: A. Detmer's culture solution; B. Detmer+phosphotungstic fraction (17 parts per million); C. Detmer +silver fraction (0·35 parts per million). The average total area of thirty plants was 112 sq. mm., giving an average area of 3·7 sq. mm. per plant. The average results of growth each week in the two dishes of each series are given in the following table:

—	Number of Plants					Total Area in sq. mm.					Area of Individual Plant in sq. mm.				
	Start	1st Week	2nd Week	3rd Week	4th Week	Start	1st Week	2nd Week	3rd Week	4th Week	Start	1st Week	2nd Week	3rd Week	4th Week
Series A	30	78	155	292	562	112	224	382	612	1086	3·7	2·9	2·5	2·1	1·9
Series B	30	83	160	303	577	112	352	639	1129	1949	3·7	4·2	4·0	3·7	3·4
Series C	30	91	175	323	669	112	415	771	1362	2678	3·7	4·5	4·4	4·2	4·0

7. *On Fossil Fungi and Fossil Bacteria.*

By Dr. D. Ellis.

An investigation of the ferruginous and fossiliferous rocks of Great Britain showed that some of the organic fragments in the ferruginous rocks had been in a state of putrefaction when engulfed. A study was made of the micro-organisms which were responsible for this putrefaction.

I. A fossil fungus was found in the Frodingham Ironstone of Lincolnshire (Lower Lias). To this organism the name *Phycomycites Frodinghamii* has been given.

Characteristics.—Hyphæ of two dimensions, namely, 2 μ and 3½ μ respectively. The two sizes of hyphæ were found in organic connection. There were no traces of transverse walls. In addition to the ordinary alternate branching whorls of hyphæ arising from the same level were frequently observed. In many places the threads showed thickening cushions. Some of these were apparently in association with the formation of branches and were of a supporting nature; others, however, had no apparent significance.

Some of the hyphæ had terminal dilatations of a sporangial nature, as in a few cases spore-like bodies were enclosed in them. The sporangia measured about 24 μ ($\frac{1}{40}$ mm.) and were roughly spherical. The spores were 10 μ in diameter. Probably each sporangium normally enclosed four spores. The fungus, unlike all modern fungi, had a power of attraction for iron-compounds, and in all cases its hyphæ were covered with a varying quantity of ferric hydroxide.

II. A fossil fungus was found in the Secondary Rocks in the Island of Raasay (N.W. Scotland). This fungus had the same general characteristics as the preceding, only its hyphæ were covered with a hard black membrane of a carbonaceous nature. No sporangia were discovered. It is proposed in the meantime to call this organism Palæomyces *a*.

III. In the Ferruginous Limestone of Dunliath (Inferior Oolitic Series of the Jurassic Rocks) a fossil Actinomyces was discovered. This micro-organism was found as a thick meshwork of minute threads inside fossilised animal fragments. The threads measured ·75 μ to 1·0 μ across and branched freely. It is proposed to name this micro-organism Actinomycites *a*.

IV. From nodules derived from the base of the Gault at Folkestone fossilised

animal remains were found which had been in a state of putrefaction when engulfed. Remains were found of three kinds of bacteria :

a. Bacillus I. (*Gault*). Average width $\frac{1}{2}$ μ. Length from $1\frac{1}{2}$ μ to 100.

b. Bacillus II. (*Gault*). Average width 1 μ. Length on the average 5·7 Rods had well-defined membranes and rounded ends.

c. Micrococcus I. (*Gault*). Uni- and Diplo-cocci in various stages of cell-division. Showed thicker outer walls and thinner transverse membranes. The diameter of the cocci measured $2\frac{1}{2}$–$2\frac{3}{4}$ μ. In some cases remains of cell-contents were observed.

8. *On Spore Discharge in the Uredineæ and Hymenomycetes.* *By* Professor A. H. Reginald Buller.

Throughout the Uredineæ and Hymenomycetes the spores produced upon the basidia are violently discharged.

In both groups, just before the discharge of a basidiospore, a drop of fluid is excreted where the spore is attached to the sterigma. The drop varies in size, according to the species, from one-third to one whole diameter of the spore. On discharge the drop is carried with the spore. Sometimes the drops become abnormally large, and then discharge may not take place.

In many Uredineæ the basidia are curved and the sterigmata are then placed on the outer convex side of the basidium. This causes the basidiospores to be directed toward an open space, with the result that, when discharge takes place, the spores are shot away so that they escape into free air.

9. *Fruits and Seeds.* *By* Professor F. W. Oliver, *F.R.S.*

10. *Stomata on Hypogeal Cotyledons.* *By* Miss E. M. Blackwell.

11. *The Musk* (Mimulus moschatus *L.*) *in Scotland.* *By* William Wilson.

In 1911 I found the musk (*Mimulus moschatus* L.) growing in Haughton Wood, Alford, in a low, cold habitat (400 feet). In 1914 I found it beside a well, Glack Culmellie, Cushnie, at an altitude of about 1,200 feet. Possibly these are the coldest stations known for the plant. It is also recorded as growing occasionally in Perthshire on river shingles; and there are two records for Banffshire. Thus this garden plant is gradually extending its range, and competing with the really native members of the British flora.

12. *The Life History and Cytology of* Tuburcinia primulicola *Rostrup.* *By* Dr. M. Wilson.

The conidial stage of *Tuburcinia primulicola* (known as *Pæpalopsis Irmischiæ* Kühn) was discovered by Kühn in Halle, Germany, in 1883, on several species of *Primula*, and it appears that no subsequent record of its occurrence has been made.

This stage of the fungus has recently been found in two localities in Kent on *Primula vulgaris*. The fungus apparently persists in the host-plant during the winter. The mycelium is intercellular, producing haustoria of the type usually found in the Ustilagineæ; in the spring it may be found in the peduncle, calyx, corolla, stamens and ovary, usually in the peripheral tissues of these organs. The mycelium is septate with uninucleate cells; the nuclei are small with one deeply-staining nucleolus. In the young flowers the mycelium is particularly abundant in the lower part of the corolla tube, on the dorsal surfaces of the anthers and in the ovary between the ovules. In these places it becomes superficial and gives rise to large numbers of small unicellular uninucleate conidia. The conidia in the open flower are seen as meal-like

masses, which glue together the stamens and partially fill the base of the corolla-tube; functional pollen is apparently produced. The conidia have little chance of escaping from the corolla-tube; some, mixed with pollen, are probably distributed by insects visiting the flower. Infection of healthy flowers with a mixture of pollen and conidia has so far been unsuccessful.

In the open flower conidia may be found in all stages of conjugation; they become joined up in pairs by a short connecting tube, thus producing dumb-bell-shaped structures. In the conjugating pair a nucleus passes from one conidium to the other through the connecting tube. The nuclei are then found in close proximity in the one conidium, which later gives rise to one or more germ tubes. It is highly probable that the mycelium thus produced bears the chlamydospores.

Chlamydospores are found in flowers in which conidia were previously produced. The mycelium in which they are developed is found in the superficial tissue of the placenta and packed in between the ovules.

Seeds are usually not ripened. The cells of the mycelium producing the chlamydospores contain conjugate nuclei. The chlamydospore groups are developed from coiled masses of hyphæ, and in the young condition the spores are binucleate. Later on, the conjugate nuclei fuse and the mature chlamydospores are uninucleate. Finally the tissue of the placenta, ovules, and ovary-wall disintegrate, and the spore masses are set free as a black powder in the calyx tube. Germination takes place readily in water; the process agrees with the description given by Brefeld. No conjugation of sporidia has been observed.

The fungus is frequently placed in the genus *Urocystis*, but the presence of the conidial stage, the absence of sterile cells in the chlamydospore group, and the method of development of the sporidia lead to the conclusion that it is more correctly placed in the genus *Tuburcinia*.

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13. *The Vegetative Anatomy of* Molinia cerulea.

By Rev. T. A. JEFFERIES.

SECTION L.—EDUCATION.

PRESIDENT OF THE SECTION:—MRS. HENRY SIDGWICK.

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address:—

WHEN I look at the names of many of my predecessors in this Presidential chair, when I read their addresses, or when I consider what the work of the Section ought to be, I feel that an apology is needed for my being here at all.

Let me say at once, however, that it is not because of my being a woman that I feel this. It is true that I am the first woman who has had the honour of presiding over Section L. But it is obviously very fitting that a woman should sometimes do so; and this not only because women are as much concerned with the results of Educational Science as men are—that might be said about all departments of science; nor only because the material on which education works—the human material to be educated—is approximately evenly divided between the sexes. A more important consideration is that women have the largest share in the work of education. This is clear if we take education in its widest and fullest sense, and include in it what is done in the home as well as in the school, beginning as it must with the earliest infancy. But it is also true if we limit the meaning of the word education—in the way that is constantly done, and is I think usually done in the discussions that take place in this Section—to that part of it with which the professional educator, the school or college teacher, is concerned. For the fact that the school teaching, not only of girls but of the younger children of both sexes, is mainly in the hands of women, results of necessity in there being a larger number of professional teachers among women than among men.

May it not be added that in some departments of education women have appeared to take their profession more seriously than men so far as this can be measured by the trouble taken in training for it? For I think I am right in saying that among persons proposing to teach in secondary schools more women in proportion than men have hitherto availed themselves of opportunities for professional training.

From another point of view, too, the education of women and girls has an interest which, though not different in kind, is greater in degree than that of the other sex. I mean in the rapidity of its growth and development since the middle of the last century. The development of school and university education and of technical education has, of course, been very great for both sexes. Much attention has been devoted to improving its quality and perhaps even more to increasing its quantity by making it more accessible to all classes of people. But in the case of girls and women the progress has been greater and more remarkable than in that of boys, for it started from a lower level, and notwithstanding this it would, I think, be difficult to point out in what respects the educational opportunities of women are now inferior to those of men. I say this, of course, in a general sense, and without prejudice as to controversial questions of detail such as the merits of the methods and curricula deliberately adopted for different schools.

The Report of the Schools Inquiry Commission published in 1868, in what it says about girls' education at that time, gives us a standard of comparison

and a means of estimating the progress made. It has often been quoted, but may bear quoting again. The Commissioners say :[1]

'The general deficiency in girls' education is stated with the utmost confidence, and with entire agreement, with whatever difference of words, by many witnesses of authority. Want of thoroughness and foundation; want of system; slovenliness and showy superficiality; inattention to rudiments; undue time given to accomplishments, and those not taught intelligently or in any scientific manner; want of organisation—these may sufficiently indicate the character of the complaints we have received, in their most general aspect. It is needless to observe that the same complaints apply to a great extent to boys' education. But on the whole the evidence is clear that, not as they might be, but as they are, the girls' schools are inferior in this view to the boys' schools.'

This was what could be said of schools in 1868, and is certainly in striking contrast to what could be said now. And if we turn from the schools to higher education we find this was practically non-existent for women at that time. Its absence was indeed one cause of the badness of the schools. The schools were bad because the teachers were inadequately educated. 'The two capital defects of the teachers of girls,' as one of the Assistant Commissioners (Mr. Bryce, now Lord Bryce) reported, 'are these : they have not themselves been taught and they do not know how to teach.' These defects were, of course, partly due to the badness of the schools, and the want of any standard enabling the general public and the teachers themselves to judge of their badness. So far it was a vicious circle. The teachers were badly taught in bad schools and handed on the bad results to the schools they later taught in. But the defects were partly due to the absence of opportunity for them to carry their own education beyond that of their elder pupils—to obtain that higher education which men obtained at the Universities. This was pointed out by the Commissioners, and their Report acted as a great help and encouragement to those who had already realised the need of higher education for women, and gave an important stimulus to the foundation of Colleges for Women first at Cambridge and then at Oxford.

The Commissioners' Report also greatly encouraged the movement already in progress for the improvement of girls' schools—the movement in which Miss Buss, of the North London Collegiate School, and Miss Beale, of the Cheltenham Ladies' College, were among the pioneers, and in which the opening of Local Examinations to Girls in 1865 by Cambridge was an important step. The cautious and anxious way in which the Commissioners refer to the possible effects on girls of more exacting school work and of examinations is amusing to read now. But the Report of the Commission helped in the progress of girls' education in still another way, for it was instrumental in securing the recovery for the secondary education of girls of endowments which had been allowed to lapse into the service of primary education or to be absorbed by boys; and the division between girls and boys of some endowments not specifically assigned to either sex by the founders. Twenty years ago—in 1895—the Charity Commissioners in their Annual Report gave striking testimony to what has been done both in this way and by new endowments :

'There is reason to think,' they said, 'that the latter half of the nineteenth century will stand second in respect of the greatness and variety of the charities created within its duration to no other half-century since the Reformation. And, as to one particular branch of Educational Endowment, namely, that for the advancement of Secondary and Superior Education of Girls and Women, it may be anticipated that future generations will look back to the period immediately following upon the Schools Inquiry Commission and the consequent passing of the Endowed Schools Acts, as marking an epoch in the creation and application of endowments for that branch of education similar to that which is marked, for the education of Boys and Men, by the Reformation.'

And the flow of endowments for this branch of education has not ceased since the Report just quoted from was written. As examples of it I may remind you of the St. Paul's Girls' School, the extension and rebuilding of

[1] *Report of the Schools Inquiry Commission*, p. 548.

Bedford College, University of London, and the large sums given for the domestic department of King's College for Women.

Though, however, as the Charity Commissioners say, a great impulse was given to girls' education by the Report of the Schools Inquiry Commission and the legislation as regards endowments that followed, I think that, even without these, great progress would have been made, though probably less rapidly. The desire for it was already there. Women who had themselves suffered from the previous deficiency were working for improvement, and sympathetic men friends were helping. It was becoming more and more obvious not only that women teachers must have adequate opportunities of learning, but that the home no longer in itself afforded sufficient scope for the energies of the daughters, especially unmarried daughters, of the professional classes, and that they must be trained for other useful work. The supply of suitable education followed the demand, as generally happens when the demand is strong and clear. The very mention by the Charity Commissioners in the passage I have quoted of the *creation* as well as of the *application* of endowments for the purposes of female education is evidence of the active public interest in the matter. The spirit which has led during the last half-century to the liberal endowment of education for girls and women from private sources has also led the State, and public bodies generally, to consider girls equally with boys in all public administration of education or of educational funds. The same spirit has led the newer universities without exception to admit women to their benefits on equal terms with men. And at the same time the creation of some professions and skilled industries—*e.g.*, sick nursing—by women, and the opening to them of others, together with the general movement in favour of professional training for professional work, have led to the great development of opportunities of technical or vocational training for women as well as for men.

This immense—almost revolutionary—change, as regards Educational opportunities for women, which has occurred within the recollection of people of my age, and which must be attributed largely to the efforts of women themselves, is, I think, very striking; and it certainly, as I said, fully justifies the selection of a woman to preside over the Educational Section of the British Association. The apology I feel to be needed is for the particular woman selected. For it is the Science of Education, or at any rate the Science and Art of Education, that this Section presumably exists to advance, and I am no educator, no teacher, I have made no psychological study of young people from an educational point of view, nor of the different methods of teaching suited to different ages, no statistical investigation of the influence or particular curricula in training the mind or furnishing it with useful information. I have, in short, neither made contributions to the science of education nor practised the art. Any work I have done has been on the administrative side, and I can speak only as a member of the general public—not as an expert. And what is there new, in a subject so much discussed, for a member of the general public to say? An illuminating address is, I fear, under the circumstances impossible.

Not that I regard the view of the general public as unimportant. Indeed, I am not sure that a good case could not be made out for having a mere member of the general public as such as president from time to time. The general public must, as all will admit, decide what is to be spent on education, or, more strictly, on schools and colleges and professional educators, out of both public and private income—it is for them to decide on its relation to other social and family needs. But the concern of the public with education is not merely financial and administrative. It is more intimate than that. For education is not a subject like physics or chemistry on which only an expert has a right to an independent view. There are, no doubt, aspects of it of which only the expert can properly judge, there are experiments in it which only the expert can advantageously try, and there are, of course, departments of it in which the opinion of the expert is indispensable. But without depreciating either the science or art of education, it is clear that when we take education in its widest sense it concerns everybody, and almost everybody is bound to have views about it. Each generation as a whole is responsible for handing on to the next the control over matter and mind, and the power of co-operation, which it has itself inherited from its forbears and added to, and which it must put its successors in a position to add to further. It is on this

that the progress of the human race depends; without it each generation would have to start fresh from the beginning, and we should still be in the position of primitive man.

But the larger and more important part of education in this wide sense is done first in the nursery, and then, as the child gets beyond babyhood, by means of its own observation and imitation of its elders; while much is done by experience gained in mixing with others of its own age, and much by the exercise of responsibility. The education thus obtained, combined with precepts and with tales handed down orally, sufficed for our ancestors until the increasing complexity of life made it important for the rising generation to acquire skill and knowledge which mere imitation and experience could not give. When this happened division of labour took place in this as in other departments of life, and led to the introduction of the professional educator—that is, the educational expert who has the art of imparting the needed knowledge and skill, or at least of shortening the process of acquiring them. We may observe that his services are now required by all and not, as was once the case, only by those preparing for the learned professions. This work of the professional educator is what our Section of the British Association is mainly concerned with, and the methods to be employed are best judged by the professional educators themselves. But the co-ordination of their work with the whole process of education, its place in the production of good citizens, must, as I have said, be judged, not by the professional educators alone, but by the whole body of the nation. The general public must not only be regarded as capable of exercising judgment on educational matters, but should be encouraged to feel that it is its duty to do so.

If we judge by the amount of talk which goes on about education, it would perhaps seem that the public is fully aware of its responsibilities. And yet I think there are indications that in some respects it fails to grasp them, and is disposed to depend too much on the professional educator; allowing itself to be confused by our habit of using the same word 'Education' in both the wider sense, of which we have been speaking, and also in the narrower sense of book-learning. The sense of proportion seems to me to be sometimes seriously lost from this cause.

I was impressed with an example of this exhibited a little while ago in a correspondence in the *Times* about the employment of the older boys in the elementary schools of country districts to do some of the work on the farms in place of farm-hands who have enlisted. One group of the correspondents, looking at the question from the point of view of agriculture, thought the advantage derived by the boy from his last year of school training was of small value to the country compared with the work he could do on the farm. The other group, looking at the question from the point of view of the school, thought it monstrous that what they called the 'education' of the boy should be in any way curtailed. I am not at the moment concerned with the controversy itself, nor am I taking the side of either group of disputants. There is, of course, much to be said on both sides, and the decision should probably vary with the locality, and the work, and the farmer, and the boy. But what struck me was that all the disputants seemed to regard education as beginning and ending at school. None appeared to think of it in its wider sense. None referred to the great effect it might have on the boy's future life and character to feel that in a grave national crisis he had 'done his bit'—an effect which would perhaps be all the greater if he felt he was sacrificing something to make up for which special effort might be needed later. I have seen the view of the gain to boys and girls from helping in the emergency put forward since, but not in the particular newspaper controversy in question, nor, I think, in connection with the loss of a year of schooling.

And there was another aspect of the question which did not seem to excite attention. I mean the possibly bad educational effect, in the wide sense, of preventing the boy from doing the work. To keep him at school, if he was conscious that his services were needed elsewhere, could not but tend to concentrate his attention on himself and the importance of his own schooling, and could not but tend to produce to some extent the deplorable temper of mind which leads some young people, a little older than the schoolboys over whom the controversy raged, to regard self-development as the aim and object of

existence. This is certainly not the attitude of a good citizen—and to produce good citizens should, as we probably all agree, be the principal aim of education. The particular difficulty to which I have referred seems inseparable from compulsory education, and probably cannot be altogether got over. The thoughtful girl of twelve, not absorbed in herself, must sometimes wonder whether her school-work is really as valuable as the help she could give her mother in some special difficulty or strain, except on the assumption that her own development ranks above all other objects.

Of course, the higher the relative value we put on scholastic education the less important will the loss of other educational influences appear to us. And perhaps at this point I had better frankly confess—what is, I fear, another defect in my qualifications as President of the Educational Section—namely, that I am not an enthusiast about education in the same sense that most of my hearers probably are. I read the other day in a review of the life of an American educationist that—

'He was penetrated with two characteristics which are the saving clause of the American and every other democracy, a reverence for learning and a flaming belief in education as the condition of success in any scheme of popular self-government.'

In the reverence for learning I am with him, but I could not describe my belief in education—education, that is, in the sense here meant, namely, school and college education—as 'flaming.' I cannot, for instance, believe, as some seem to do, that by keeping children a year longer at school we should regenerate mankind, or at least secure as a matter of course great improvement. Why, you may ask, if I am not an enthusiastic believer in education, have I spent so much of my life—my time, my energy, my means—in helping to provide opportunities of University education for women? The answer is that I do believe very much in giving to as many people as possible educational opportunities—meaning by that in the first place the means of preparing for their work in life. Those who are going to teach, for instance, must obviously learn first, and, as I have just reminded you, women's opportunity of doing this was lamentably deficient half a century ago.

But secondly—and this is not at all less important—I mean by educational opportunity the means of satisfying intellectual curiosity, every spark of which should be fostered. For it is to intellectual curiosity that progress in knowledge, including physical science, is mainly due. And intellectual curiosity is an important adjunct to the mental processes involved in understanding the world we live in, a valuable aid in the formation of a good judgment, and a great assistance in practical life. Intellectual curiosity and æsthetic sensibility are, moreover, the mainsprings of culture—that is, of some of the highest pleasures we can enjoy.

You will doubtless agree with this, and will agree, further, that without intellectual curiosity no amount of accumulated information can be properly assimilated, or will produce either culture or knowledge of permanent value. In its absence the pupil may pass through school and college with little advantage apart from discipline, beyond the acquisition of elementary skill in reading, writing, and arithmetic, and if he has a good memory a barren knowledge of some facts. You will probably add that it is one of the most important functions of the teacher to endeavour to produce this intellectual curiosity when absent or in abeyance, and that the zeal of the professional educator in this direction is a strong reason for enthusiastic belief in school education. It would be, I grant, if we could hope that the teacher's success would always be equal to his zeal; but notoriously this is far from being the case, and the failure is by no means always due to want of intelligence in the pupil any more than it is due to want of capacity in the teacher. In many cases, in all classes of society, the spark of intellectual curiosity—the response in the pupil's mind to educational stimulus—cannot be fanned into flame through book-learning alone, and yet may be there all the time ready to burst forth when it comes into contact with the needs of actual life and work. It may even be there, and fail to respond to imposed lessons, while it would blaze up if the pupil could by any means be induced to desire to learn before he is taught. It is partly because it is so important, if and when the desire to learn comes, that the boy or girl,

man or woman, should be armed with the instruments which may give them independent means of acquiring the knowledge they desire, so far as this can be acquired through books, that we compel parents to send their children to school. No doubt, however, an even more important reason is our now almost universal use of reading and writing as a means of communicating with each other. The more widespread these arts are, the harder it is for anyone who has not acquired them to keep abreast of his fellows. But even now it would, of course, not be impossible, and the use of such phrases as compulsory education, in which education merely means the reverse of illiteracy, tends, I think, in itself to obscure the apprehension of what education really is and to reduce the general sense of responsibility for it, and particularly that of parents.

Many years ago before the days of compulsory education, or at least before it had time to produce any effect, I knew a man in the South of England who had had no school education, or practically none. I believe he could read a little with effort, but he could neither write nor keep accounts, so I was told. His wife did these things for him when they were necessary. He was, however, a good farmer, farmed a considerable amount of land, and acted as manager or agent under the landlord for a large estate. He knew his business thoroughly, had the power of managing men, and was much respected. It is impossible not to regard such a man as a more valuable member of the community, and a better-educated man in some respects, than many of those who climb the educational ladder to become clerks in an office. But, of course, such a man must have regretted that he had not had opportunities of schooling in his early youth—that he had not acquired the art of writing while he still had leisure. The want of the three R's must have been a serious handicap, only overcome by unusual ability. And, in fact, no one now doubts that it is almost as important to acquire these elementary arts as to learn to speak or walk. It is with the question of carrying school education further that doubt arises whether it is really the best education for everybody, and whether we ought to regard the person whose scholastic education has been longest, or who has succeeded best in examinations, as therefore necessarily the best educated.

I do not mean in saying this to set the practical man above the man of learning. Of course we want both, and we should like our schools to help to develop both. The value to the world of good scientific and literary work is enormous. And so far as science is concerned the British Association exists to bring home to the general public its value and interest, and consequently the importance of men who can advance it. Nor do I mean in what I have said to suggest any divorce between practice and learning. The business of most of us is practical, but what is to be desired is that everyone capable of it should combine practical ability—whether in manual work, or in organisation or administration, or in any other line—with a desire to learn; and that not only in relation to his work in life, but in a wider sphere. And, of course, we must wish that the means to satisfy this desire should be within everyone's reach. My point, therefore, is not that learning is not valuable, but that it is of little value unless it meets a desire in the learner's mind. And here the parents come in The required attitude of mind is much more likely to be inspired by parents who possess it, than it is by the school. Or let us say that those children are most likely to grow up with it whose parents combine with the school to stimulate it. Unfortunately the result of compulsory primary education has not been to promote any sense of responsibility in parents as regards this; at least that is my belief. And I may, I think, appeal to Scottish experience in support of it.

The institution of parish schools is, as is well known, older in Scotland than in England. They date there from the Reformation, and were part of the ecclesiastical organisation initiated by John Knox. In the scheme drawn up by him and his colleagues education had a great place. The parish schools, in which Biblical instruction was foremost, were put in charge of the Church and long needed its efforts for their maintenance. Starting in this way the zeal for school education had become traditional. All respectable parents aimed at giving their children the best education they could. There was a strongly rooted sense of duty in the matter, and this from a double motive. They sent their children to school not only to help them to get on in the world, but because of the traditional association of knowledge and religion. Observe

the educational value of this second motive. I am not looking at it from the religious point of view—that is not my business to-day. But as an instrument of culture the value of a desire for learning, based on something other than its relation to worldly success, is obviously great. It may be that the school education actually prevailing in Scotland is better now than that of fifty years ago, that the examination of the school inspector is more searching if less stimulating than was that of the Presbytery, that the average or backward child is less sacrificed to the clever one than used to be the case, and that general intelligence is more developed. But the parents, who felt their children's schooling to be their private concern, valued it more, took more personal interest in it, and felt more personal responsibility for their children's progress than parents can do now. And it is a serious question whether the loss of this close link with home life has not had a bad educational effect, taking education in its wider sense, which is not compensated for by possible improvement in the schools.

I must admit that in saying this I have in mind only a limited area. I have made no wider investigation. The population I am thinking of is an entirely rural one in a purely agricultural district in the South of Scotland, with which I was intimately acquainted as a young woman, and which I revisit from time to time. In such a district compulsion to send the children to school was unnecessary. It probably was required in the large towns and the more industrial parts of the country. I do not complain of the introduction of compulsion, but it did strike me at the time of its introduction that it was of very doubtful advantage in my own part of the country; and this impression has not diminished since.

To see if it was shared by others I wrote to a friend, more familiar with the district than I am now, to ask whether he did not think that parental interest in the children's school education had decreased, and also whether he thought that, as judged, for instance, by the books they borrowed from the parish library, the grown-up population was less inclined to serious reading than they used to be. I received from him a very interesting reply. He agreed with what I have just said as regards the first question, and after speaking of the warm and genuine wish in old times to give the children a good education, added :

'The parents might, indeed, let their older children be absent for short times from school for light farm work or the like. But this was more than made up for by the zeal with which they were sent to winter evening classes, which could be gathered then far more easily than now. It is an unfortunate effect of legislation that it has largely deprived us of the great asset we had in the keenness of parental interest. It came about in this way. Government made it compulsory that no child should be employed in wage-earning who had not passed the fifth standard. Almost instantly the ideal of our people was lowered. A child was "educated" who had passed the fifth standard! And when by and by Government made it compulsory that a child should be at school till fourteen years of age, the parents in many cases felt this hard upon them, and our School Board every year has applications for permission to children to work before they are fourteen on various pretexts. I do not say that our people are not interested in their children's education. They still inherit that interest. But *compulsion*, and the fact of the responsibility being taken by Government, has greatly changed their attitude.'

With regard to my second question—'Whether there is in country parishes as much reading of serious books, books of weight, history, travels, &c.'—he says he 'must answer *No.*' He thinks that the young people are perhaps more intelligent than they used to be, 'but the reading is in enormous proportion novels and very light literature.' He goes on to tell me of an old man who died two years ago 'of the finest old Scottish type—devout, independent, interested in religious reading, in lives of men like Livingstone, in travels (he was reading Nansen in his ninetieth year and most interested in his nearing the Pole). But the list of books in his steady reading from the library here was of quite different character from that opposite other names in our catalogue of the same rank.' He says also that forty or fifty years ago good audiences could be got for lectures—historical, travel, &c., but that now a good

audience can only be got for concerts, entertainments, or at most lectures with lantern pictures. All this seems, as far as it goes, to show a diminution in culture, in capacity for the higher intellectual pleasures, in fruitful curiosity. My correspondent is not prepared, however, to say that this change is due to changes in school education. It comes, he thinks, 'of the different spirit in young people, less under authority, indulging more in pleasures, not pressing hard or thinking they need this in order to get on.' He thinks, in short, that the young men now are more self-indulgent and less energetic than they were, and he looks to the nobler spirit which the War has called out to carry us into better ideals of life. He may be right in thinking that causes independent of school education have produced the result. But we must admit that if it is true that, concurrently with a school education improved in some important ways, there has been a diminution in intellectual interests—in culture, in short—the school education has at any rate failed in one of the objects aimed at.

Well, you must take these views about a particular country district for what they are worth. Facts observed among a comparatively small number of people may not represent the average. Moreover, my correspondent and I are both old—we could not remember, or think we remembered, the state of things fifty years ago if we were not—and you may, if you think proper, discount what we have to say, on the almost proverbial ground that old people put the Golden Age behind them. I am not, however, myself conscious of any such tendency. I believe very much in progress, and look forward to a gradually improving world, and I believe we are on the whole improving in educational ideals and educational methods as in other things. But it behoves us to watch what we do, and not to acquiesce, if we can possibly help it, in loss on one side without being very sure that it is more than compensated for by gain on the other. The loss of the parents' real co-operation where it has existed, and the failure to gain it where it has previously been absent, is serious. It is serious even if it is limited to the intellectual side of education and does not extend to the formation of character, as I fear it sometimes does. With the greatest zeal the schoolmaster cannot replace the parents, nor even the parents' influence in producing the right attitude of mind in the pupil. And it is at the very least doubtful whether the better teaching which improved methods secure to the pupil can make up for any loss of spontaneous desire to put his own mind into the effort of learning for learning's sake.

And so I come back to the point that the general public must be encouraged to take its share even in the part of education carried on at school and college, and in particular those members of the general public who are parents of pupils. But this conclusion is rather barren, for I have no very definite plan to suggest for carrying it out. The State cannot now, even if it would, abandon the responsibility for the elementary school education of the children, and even if it could it is more than doubtful whether it would be desirable. For though we have now secured that all parents shall themselves have had school education, we still cannot trust them all voluntarily to give that advantage to their children. So the drawback must be put up with that parents cannot feel the same degree of responsibility resting on themselves when the responsibility is undertaken by the State.

It is to be hoped, however, that we shall be very careful how far we entrust to the State the regulation of education higher than the primary. Bureaucratic regulation may be well adapted to produce German *Kultur*, but it is not the way to secure the attitude of mind which leads to freedom, independence of thought, and culture in the best sense. And it is very apt to lead to want of independence in the teacher.

Probably our best hope for progress in the right direction lies in movements like the Workers' Educational Association, where we have voluntary effort put forward to satisfy spontaneous desire to learn. As this movement extends we may hope more and more to get a generation of parents who, having themselves experienced intellectual curiosity and the joy of satisfying it, who, having themselves felt the gain of a wider outlook on men and things, may by their example inspire their children with a similar disinterested desire for learning and culture.

The following Papers were then read :—

1. *The Place of History in Education.*
By Professor F. C. J. Hearnshaw.

Before the place of history in education can be determined, the aim of education as a whole must be agreed upon. There is not at the present day the same simplicity of aim as there was in ancient and mediæval times; but in a democratic country like Britain the civic aim must necessarily be the dominant one. The main purpose of national education is to produce good citizens. What part can history play in the attainment of this end?

Until recently history, regarded as an instrument of education, manifested several serious defects. It was written from a partisan point of view; it was unscientific in method; it was unduly restricted in its scope. Recent changes, however, in the study and writing of history have gone far to remove these defects and to provide a valuable and trustworthy instrument, even though history on its literary side has thereby suffered.

The educational functions which history subserves may be classified as (1) *Technical*, in the case of statesmen and others; (2) *Intellectual*, in so far as it trains the imagination, shows the sequence and cause and effect in human affairs, and gives practice in the weighing of conflicting evidence; (3) *Moral*, in that it widens the mental horizon, elevates the character by bringing it into contact with great men and large affairs, arouses sympathy, develops impartiality, and teaches 'awe at the prodigious manysidedness and endless significance of human activities'; (4) *Civic*, in that it provides a school of political method, a storehouse of political precedent, and the basis of future political progress. It further serves a purpose which may be termed (5) *Philosophical*, since it furnishes man with some data for the solution of the ultimate problems of knowledge and being.

These generalisations may be illustrated from the light which history throws upon the causes of the present European crisis.

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2. *Methods and Content of History as a Subject of School Study.*
By Professor Ramsay Muir.

History, like other subjects, has to serve a double end in the school curriculum. (A) It provides training for certain qualities of mind, imagination, judgment, the habit of considering events in the light of their background, the power of weighing human testimony without undue credulity or undue scepticism, and the habit of tolerance, arising from the sympathetic appreciation of conflicting points of view. (B) It provides the pupil with a body of knowledge useful for the purposes of his life, and especially with an explanation of the society in which he lives. The scheme of an historical curriculum, and the way in which it is handled, must depend upon the relative importance attached to these two ends.

If we think only of mental training we shall conclude (*a*) that it does not matter what period is studied, and (*b*) that it is best to study a limited period, where the teacher has full and first-hand knowledge, and where by the use of contemporary narratives the events can be seen through the eyes of the actors. This forms the real justification of the long ascendency of classical studies, which gave the intelligent student a really intimate knowledge of decisive periods in the history of Greece and of Rome, and therefore achieved, often in a remarkable degree, the intellectual benefits of historical training. If equally good results are to be achieved in the modern field, the same methods, or similar methods, must be followed.

The demand that history should be used to explain his world to the pupil is, however, now predominant; and it seems to exact a range of study that puts out of the question the intimate study required for the realisation of the first aim, and drives us back upon arid outline surveys, supplemented at the best by the disconnected collections of excerpts known as source-books. For

this second purpose the student ought to cover all English history, economic history, the history of the colonies and dominions, and the general history of Europe. This range is far too wide to make any solidity of knowledge possible, and the pupil is apt to be fed on formulæ and dead (because disorganised) facts.

What is the result of the ordinary school curriculum upon even an intelligent boy? (1) He knows the traditionally emphasised facts about English political history, but seldom for any period later than the seventeenth century; and he has no such grasp of (say) mediæval civilisation as his predecessor sometimes had of classical; (2) he knows, as disconnected facts, a few episodes of English economic history, but has no sense of the organic development of a society; (3) he knows as a rule nothing at all about India or the self-governing colonies; (4) in a few cases he has been through a very slight outline survey of European history, but has no sense of the 'personalities' of the nations, the character of their civilisation, and the nature of their aspirations. He has *not* been equipped with a body of knowledge that in any real sense makes the world more intelligible to him; and on the other hand he has not enjoyed the kind of training that would cultivate the mental qualities already described.

The two things that make English history worth studying are (1) the development of self-government, and (2) the expansion of the British race and of their ideas over the face of the globe. The first of these involves a study of constitutional history, which is too difficult to be successfully undertaken by immature minds. Our pupils in this field usually know only formulæ and disconnected scraps of 'antiquities,' which (when divorced from their context) have in them no mental nutriment, and stand in no intelligible relation to the world which the pupil knows. Of the second theme, as has been already said, he knows nothing.

Is there any means by which the two aims of historical study can be reconciled and combined? I suggest that we have, in the story of British expansion during the last four centuries, a theme which would make this possible. (1) The theme has a strong narrative interest, which will appeal to boys. It has both unity and variety. It remarkably illustrates the geographical factor in history. (2) It introduces the political problem in the simplest and clearest form, and illustrates the ideas and methods of self-government in a way far more intelligible to young minds than any narrative of the thirteenth or seventeenth century struggles. The essential character of British civilisation shows itself most unmistakably, and in clearest contrast with the civilisation of other countries, in the field of extra-European expansion. (3) Large blocks, at any rate, of the subject lend themselves to study in contemporary narratives, and an excellent source-book could easily be made, consisting not of snippets, but of long chapters by contemporary writers. (4) The development of the economic position of Britain, and, indeed, the general development of Western civilisation in its economic aspect, comes out more clearly in this story than it can easily be made to do in a narrative of English history on the ordinary lines, because colonisation and trade have been closely related throughout. (5) All the principal nations of the world, European and other, appear on this great stage, and express their national characteristics in their colonial activities. As Britain has been not only their rival but often the inheritor of their work, some understanding of that work becomes necessary; and this means the appreciation of the nations as personalities.

Such a scheme of studies, limited in its range in one way, of world-wide range in another, having a central thread and at the same time a great variety, could be so handled as at once to help the student to understand not merely the British Empire, but the world of to-day in all its interrelations, and to appreciate that conflict of national interests and national ideals which is the stuff of modern history. But it could also be used (because some intimacy of study would be possible) as a means of realising the intellectual aims of historical studies.

The obstacles in the way of such a scheme are considerable, but they are merely practical difficulties about text-books, examinations, and the like, capable of being overcome.

3. *History as a Subject of School Study.* By J. E. Morris, *D.Litt.*

There is a somewhat urgent need that schoolmasters and schoolmistresses should be freely consulted, because they know the capabilities of the youthful mind, immature and impressionable as it is, better than university authorities. Those who know the pupils in the class-room should have a voice in the choice of subjects rather than those who only see the answers written in examinations. The former resent, perhaps too keenly, the methods and the criticisms of examiners; the latter find fault, perhaps too freely, with the teachers. The friction, such as it is, can be lessened.

Firstly, it is necessary to distinguish between the really promising, the average, and the dull boys.

The promising boys, possibly candidates for scholarships, need, and usually find, scope; the chief danger, however, is that too often they are expected to limit themselves to political history, and are judged by literary capacity, whereas enthusiasm in some special branch, *e.g.*, archæology or social developments, may be a sign of greater promise than mere literary expression. One hears that an attempt is being made to bring classical and modern languages more definitely into the history scholarship examination; in theory this is excellent, for an understanding of Thucydides or Cicero as an original authority, or an appreciation of some problem of the Revolutionary era expressed in a free French composition, would at once mark out a boy as a possible scholar; but in practice it is much to be feared that the linguistic side would be made too prominent.

But it is for the average boys that the most careful legislation is required. They ought not to be harassed by too many examinations and too many subjects; and in general they ought to be taught as much as possible by one man, the form-master, for he only can properly judge where to put on special pressure, and where to relax, as examination time draws near. Where, however, the form-master is not sympathetic and the specialist must be called in, it is imperative to combine two or three consecutive classes under one man. The extreme case of an average boy presenting eight subjects and taught by eight men, each demanding the lion's share of the time, is either pitiable or farcical, and the result is either overwork or a clever laziness which plays off the teachers against each other. In most cases history suffers, and is either crowded out or perfunctorily taught; worse still, the right sort of history is not always put on the syllabus, but that which can be most easily crammed. Examinations of the 'School Certificate' and 'Matriculation' type are meant; hardly ever are the average boy's one or two strong points allowed to come into play, and especially is this the case in history. At the present crisis it is opportune to insist that his school studies should not be confined to England and to events before 1837; he both likes and should be encouraged to study European problems, even if he finds it hard to be accurate.

The average boy suffers badly because of the dullard; often, of course, the dullard in one subject is the brilliant scholar in another, and outsiders in reading reports forget that the strong criticisms of examiners do not refer to the same boys in all subjects. Teaching to the bottom boys of a class to force them through an examination is utterly unfair to the many average and few brilliant boys.

Secondly, the rigid division of subjects is quite wrong. Geography and English ought not to be marked off from History. An ideal paper would contain absolutely elementary questions in all three, the standard being fixed by syllabus, and 20 per cent. of marks allotted; then a large number of alternative questions should be put, being worded so as to allow the writer to show how wide his reading is in political, social, geographical, and general subjects. As matters are now, one can offer no suggestions except on the lines of examination tests.

4. *The Method and Content of History as a Subject of School Study in Elementary Schools.*

By J. A. WHITE.

The present situation has brought home to the most unimaginative how much our life is bound up with the outside world, the meaning and value of our own institutions, and that we, perhaps more than any other nation, are dependent upon world conditions. A democracy ignorant of its surroundings is, obviously, a serious danger in a democratic State. Some ideas of world conditions are, therefore, essential. Nor can these ideas be limited to present conditions, because tradition is such a tremendous intellectual force in the whole national organism. Definite history teaching, of the most elementary character, would have made the task of explaining the causes of the present crisis a comparatively easy matter. Again, how frequently one hears the complaint that it is most difficult to interest the elector in anything beyond his immediate environment! And this at a time when the State is forced, more and more, to interfere in the affairs of the individual. Enlightenment in this direction is a necessity, if we are to avoid, on the one hand, slavish obedience, or, on the other, a more or less hostile indifference From these considerations it follows that we must, at least, introduce our youth to some knowledge of general, social, and constitutional history.

This is a difficult task. Plainly we must throw overboard much that we have hitherto considered necessary. Already dates, royal personages, and battles have felt the shock of the newer tendencies in history teaching, and doubtless in many cases the abandonment of these has been overdone, and too much stress in the more advanced schools has been laid upon economic factors. But even when thus pruned, the selection of matter suitable to cover the ground indicated above is a very difficult task.

Three things should be kept steadily in view : (1) the matter must be such as will appeal to the child ; (2) it must have development as its cardinal feature; (3) it must, in some measure, explain modern conditions. If this is done, neither kings nor queens, nor great men and women, nor economic and social development will be neglected.

In general history we must keep to the broadest and most interesting events, and, in a sketch of this kind, sometimes one group of peoples or events, and sometimes another, will occupy the central theme, but the general result will be the gradual unfolding of the present grouping of the great world powers, with the British Empire in its relation to them. The world geography taken about the same time will be of considerable assistance.

In social and economic history we have a somewhat easier task. The great stages in our social development, especially up to the end of the eighteenth century, are few. A continuous story is fairly easy to construct. In conjunction with local history, its appeal to the child is direct. But while the communistic side of the subject will be strongly marked, the importance of the actions of individual men and women must be emphasised.

In constitutional history we think of the future elector. Therefore the story of Parliament, with the main landmarks in the growth of political freedom, is what is necessary. This course will be of such a nature as to impress the lesson, that concurrently with greater freedom come more duties and more responsibilities.

The accomplishment of all this depends primarily upon competent teachers with the necessary historical equipment. But it is possible to do much with the resources at hand. Much general history forms part of the Scripture lessons, and can also be dealt with in the story lessons. Certainly we could get almost all we need down to Roman times. The general biographical stories, so frequently given for history to children from the ages of 6+ to 8+, could be arranged in chronological sequence. Thus, while the imagination and the emotions are being cultivated, the child is acquiring some sense of historical sequence. From the ages of 8+ to 10+ a series of stories based upon the social development of the home country, coupled with a study of local history, would give a sense of development. From 10+ to 12+ British history could

be taken dealing in the latter year with the growth of the British Empire. From 12+ to 14 or 14+ the time for historical instruction might be lengthened in order to cover the three courses in general, social, and constitutional history outlined above.

To assist in this work the Time Chart should always be in use. Maps, plans, and, in some cases, models, containing the necessary data for intelligent interpretation of events, as well as a good atlas, should always be at hand. Pictures, especially contemporary ones, are particularly useful. Source books and original documents need a competent teacher, or sufficient authoritative explanatory matter. Contemporary literature is most valuable. Museums supply isolated items to fill up the picture. Text-books and other reading matter should be under the guidance of the teacher.

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5. *History in Elementary Schools.* *By* Professor T. F. Tout.

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6. *Instruction in Ethics and Politics.* *By* Miss E. E. Constance Jones.

In discussing the teaching of any subject, we may consider (1) *What* is to be taught—the subject-matter itself; (2) *Whether* it is to be taught; (3) *How* it is to be taught.

As regards history, we are all agreed that history should be generally taught in schools, and should be a subject of study at universities, and, to some extent at least, at training colleges, and perhaps we all know roughly what we mean by history. So the great question here is : *How?*

As regards ethics and politics—the study respectively of private and public duty—of what men ought to do whether as private individuals or as political factors of an organised community—it might be thought that the most debatable questions are : (1) What account can we give of these subjects? and (2) Should they be taught in schools, in the universities, and in training colleges?

It seems, however, on reflection, that ethics and politics—though, on the whole, the systematic study of them is strangely neglected—are just as familiar and all-pervading as history—that instruction in history inevitably carries with it some instruction in ethics and politics. At every step in history, from the very beginning when an action, a king, a hero, a traitor, a coward, a government, a war, is pointed out as good or bad, ethics and politics are taught —though indeed only by-the-way. And the connection becomes closer and deeper and more multifarious as the study proceeds.

So here, again, what is prominent is our third question, How? which we may enlarge to How, When, Where, and How much?

A most suggestive hint as to the best way of *consciously* using history or legend—descriptive tales whether fact or fiction—as a starting-point of ethical instruction, is given by Robert Browning in a little poem which tells how his father first made known to him the heroic story of the siege of Troy—'piling up chairs and tables for a town.' The progress so begun—'thus far I rightly understood the case, at five years old'—ends in the pupil's absorbed study of Aristotle's 'Ethics' in the original. The whole suggestion seems true to life and thought—the first crude, but visible and tangible, presentment being succeeded by acquaintance with the 'Iliad' itself, and that by admiring contemplation of unembodied virtues.

At later stages a systematic answer to the question : (1) *What* is it that is to be taught as good in conduct? is insistently called for, because differences of opinion arise as to what it is that is Good and Bad. But perhaps at any stage Bishop Butler's view that good conduct may be summed up under the heads of justice, veracity, and regard to common good, is likely on consideration to be accepted. Virtue thus understood is 'that which every man you meet puts on the show of.'

And if justice, veracity, and regard to common good can be brought—they can—under the one rubric of benevolence, our first and essentially important question : In teaching ethics and politics *what* is to be set forth

as good and bad? is answered—in the briefest possible way indeed, and in the barest outline—but yet adequately, if the answer proves to be valid and to cover all the ground.

The principal part of this paper is devoted to trying to show this with as much brevity as is compatible with clearness, and insisting particularly on the vital importance of having the *same* fundamental principle in politics as in ethics.

No theory of conduct, of course, can escape the question, Why should we accept it? How do we know that it is true? This is a matter of method, and the theory here advocated is prepared with a very impressive answer—an answer which, when set out at length, offers also a solution of the very fundamental inquiry: *Why* should I do what I see to be right?

There remains for further consideration our complicated third question: *How* ought ethics and politics to be taught? This I make an attempt to answer very briefly, and endeavour incidentally to indicate various interesting connections between teaching of history and instruction in the theory of conduct, and to point out some of the immensely valuable services which systematic ethics and politics can render not only to history, but also to that many-sided life of man which is the subject of historical study.

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7. *Education and British Ideals.* *By* Professor R. S. Conway, *Litt.D.*

Many complaints have been heard in the course of the present War that British education is being proved inferior to German in point of technical training. Even if this be granted, it does not prove that the German system as a whole is better than ours. The Germans had, no doubt, applied to war all the resources of modern science; yet the object of education is not merely to make good tools but to teach men for what ends to use them. No system is sound which does not, as Plato taught, awaken some intelligent affection for great ideals of conduct, and these could only come from the literary side of training. Now one of the ideals which the literary side of British education has nourished is absent from the Prussian mind, though not from the older and humaner traditions of Southern and Western Germany, and it is Prussia that has directed German education for the last forty years. This ideal is the love of freedom, understanding by freedom free government. The desire and respect for this is by no means spontaneous in human nature. Has any scientific discovery conferred vaster benefits on mankind than that of freedom in this sense? It was the Greeks of the sixth and fifth centuries B.C. who first introduced free government into the world, and saved it at the outset, at great cost to their own generation, from being crushed by Oriental tyranny. From them the faith in freedom has passed in a clearly traceable line through Roman literature and through the Roman municipal system to all the communities of the world in which freedom has taken root, including even the Hanse republics, for, as Freeman pointed out, our Teutonic ancestors hated the very idea of a town, and the notion of a charter granted by the Emperor came straight down from the Roman Empire. No educational changes, therefore, could be approved which injured this great tradition of British training. The University of Manchester has shown its faith in it by founding side by side with the fourth Chair of History a fourth Chair of Classical Studies, devoted to Imperial Latin.

THURSDAY, SEPTEMBER 9.

The following Report and Papers were read :—

1. *Report on Museums* —See Reports, p. 262.

2. *The Place of Museums in General Education.*

By Hon. Professor W. Boyd Dawkins, *M.A.*, *D.Sc.*, *F.R.S.*

The value of museums in general education depends upon their arrangement and their being classified so as to show the true relations of the various objects to one another. I propose to lay before the Section a scheme of classification based on my experience in Manchester, dating from 1869, in combining various scattered collections into one museum, which is now of equal service to the University, to the various schools and institutions of the district, and to the general public. What has been done here on a fairly large may be done with equal success on a small scale elsewhere.

The difficulty of co-ordinating the widely different groups of objects of human interest has been overcome by the adoption of the principles of time and evolution as the basis of classification, as seen in the following scheme.

Scheme of Classification carried out in the Manchester Museum.

Modern History of The Earth	VI. Animals | VIII. Man | VII. Plants	VIII. History, Anthropology, Ethnology, Art VII. Botany VI. Zoology
	V. Tertiary Life (Cainozoic)	V., IV., III., II., I. Geology
	IV. Secondary Life (Mesozoic)	V., IV., III. Palæontology
Ancient History of The Earth	III. Primary Life (Palæozoic)	
	II. Rocks	II. Petrology
	I. Minerals	I. Mineralogy

In this scheme the minerals are placed at the bottom because they are the materials forming the rocks. The existing animals and plants stand at the top in their true relation to the geological record, and the various changes, which they have undergone in becoming what they are, fix the geological age of the rocks in which they lie.

The place also of the collections illustrating History, Anthropology, and other subjects grouped together in No. VIII., in close relation with those of Zoology, Botany (VI., VII.), and Geology (I. to V.), is fully justified by the connection between those sciences, and more particularly by the appearance of man in the geological record. The continuity is so marked that the present face of nature may be taken to be the current, but not necessarily the last, of the stages of the evolution of life in the Tertiary Period.

A museum arranged on these lines, made intelligible by lectures and addresses as in Manchester, cannot fail to become an important instrument elsewhere in a system of education in which the study of things is becoming at least as important as the study of books. It is now doing its work in Manchester.

3. *Military Training in Schools.* By Rev. A. A. David.

1. *Its Bearing on National Needs.*

The question is not altogether separable from the wider question of Universal or National Training.

It is fair to point out that the recent sudden demand for a very large number of officers in all branches of the British Army would not have been met as it has been but for the careful and continually improving military practice in Public Schools for the last thirty years, but especially since 1908.

But it will be endeavoured so far as possible to discuss the School question on its educational merits alone.

2. *Suggestions for a Continuous Course.*—At Elementary or Preparatory School stages—Drill and Scouting. In Public Schools.—Ditto with Field Practice and Elementary Tactics and much exercise in handling squads, sections, &c., leading to certificate A, and at a later stage to further training for Officers and Certificate B.

3. *Effects on the Individual Boy.*—(a) *in body.* Good drill demands and induces alertness of ear, ready attention, and muscles under instant control. Physical exercises for straightening, smartening, and strengthening are probably best done as part of military training. And all this is most easily taught and learnt quite early in school life.

(b) *in capacity and character.* To prepare a man to be a soldier means to produce in him faculties and powers which are of more than merely military value, *e.g.*, in connection with the giving, receiving, and transmitting of orders, the appreciation and enjoyment of smartness and orderliness, and later on responsibility, initiative, and leadership.

(c) *in intelligence.* Experience has proved the educational value for older cadets of tactical problems for Certificate A, map-making and reading, and other field work.

4. *Effect on the School.*—Here again experience has shown that a good Training Corps reacts on the life of the whole school. For instance, in Boarding Schools it is now exerting and, it is hoped, will continue to provide a wholesome check upon the undue exaltation of games; whereas in Day Schools, where compulsory games are often impossible, it supplies a wholesome and practical form of exercise and change of interest.

And it has also been found that a really efficient corps raises the standard of discipline, and even of efficiency, in other departments of school life. But the drill must be good. Bad drill is worse than no drill. Much of the opposition to school training dates from a time when little was expected of Volunteers, before they were taken seriously by the authorities.

5. *Objections.*—The objectors fall into two classes:

(*a*) those whose hatred of all war leads them to condemn all military training whatsoever. Such views cannot fail to win respect for those who hold them. In a world of hard realities and second-bests we cannot afford to be without men who will thus continually remind us of what ought to be possible, but neither can we afford to act on their advice.

(*b*) those who fear an 'English militarism.' But why should we suppose that English boys would catch a spirit and follow an example which the whole world is recognising to be ridiculous, odious, and disastrous?

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4. *Military Training in Schools.* By J. L. Paton, *M.A.*

The present time seems to me most inopportune for discussing this question. We are all under the obsession of the war. All that I urge is based not on the present state of things but what will follow when the War is over, when mankind will have a chance, such as it never had before, to open a new era and roll the world upon a new and a better course.

I. If military training is to be made universal and compulsory in secondary schools, this ought to be part of a national scheme. Compulsion by patches

will never work. Where is this national scheme? At present it looks as if the idea was to train officers in the secondary school, and the rank and file in the elementary school. If we are to have a conscript army, serving under compulsion, at least let it be on a democratic basis, with free upward mobility and no caste about it.

II. This war is the result of ideas firmly held, resolutely and unscrupulously carried out into action. The seed-time of ideas is boyhood and early manhood. Instil the idea of war, and war will be the crop we shall reap. Already our school history is instilling far too much the idea of war. Every page of it teaches implicitly that, when nations disagree, the way they settle their difference is by means of war. And war appeals far more to the imagination of youth than arbitration. A boy is far more stirred by the Balaclava charge than by the Alabama arbitration. The teaching of history needs reforming.

But what he does influences your boy much more than what he hears. And now you propose to train every boy in the practice of arms. War is to be his chief game. I do not know whether scouting is still to have any existence, but, if so, it is to be merely as a preparatory branch for the great universal English game of war. And directly a boy turns sixteen he is to be turned out of the scouts and don the khaki. That means that scouting will be shorn of one of its most valuable training qualities: the training of the senior boy in responsibility. Have the originators of this proposal thought out the inevitable psychological result of their proposal? Steadily, day by day, they are going to drill into our boys, at the most suggestible period of life, the idea that *the* service which their country requires of them is fighting.

III. One would have thought that this war had been sufficient object lesson to us never again to turn a nation into a barracks. Why did the European peoples go to war? Because for generations they had been living for war and preparing for it. If our present experience teaches us anything, it is the impotence of conscription to save us from war. Europe is suffering from the fever of war. What produced it? Conscription and military preparation. What remedy is proposed to cure the patient? The authors of this proposal have only one prescription, 'Repeat the conscription dose—the mixture as before, only make it stronger and increase the amount.'

IV. What is the principle we are fighting for? Is it government by consent, or government by coercion? Is it a nation drilled and regimented and dragooned by the War Office, or a nation free and spontaneous in its service, mutually co-operative in its organisation?

Let us get down to the root difference between the two parties to this debate. Neither of us holds with Treitschke that the war is good or desirable in itself. Both of us agree that the present state of things is of the devil. But my opponents accept it as a thing that must be. 'We have to live in the world as it is.' Our position is the exact opposite. 'We have to make the world as it should be; and it is in our power to do it.' We fail in our highest duty if we do not make some advance towards this.

There remains the question: on what other lines can national security be assured? First, smash Germany. Then summon the Hague Conference. Utilise to the full the reaction against war which is sure to set in. Throw all the highest statesmanship, moral wisdom, and strongest will-power of the nations into the ending of war. If we do not end war, war will end us.

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5. *Military Training in Schools.* *By* A. A. Somerville.

The best introduction to military training is probably to be found in either the Swiss system, which includes not only exercise and drill but also games, or in the Boy Scout movement; the results obtained by the latter are great and encouraging, and even extreme pacifists will not object to its spread all over the Empire. In the secondary schools, however, definite military training should be commenced; when the leaving age is eighteen or nineteen there is full opportunity for this, but where the leaving age is sixteen the difficulties are much greater.

The Volunteer movement in schools corresponded closely with its progress in the country; in 1860 two Eton Masters formed the first Cadet Corps, and since 1872 the Eton Corps has almost always gone into camp at the end of the Summer Term. After the South African war the Officers' Training Corps was founded by the War Office, with the special intention of forming a source from which officers for the Regular Army could be drawn; the result has been to make drill, shooting, and field work at school keener and camp-life more strenuous; and, outside the Regulars, the O.T.C. is one of the few organisations able to provide officers and men at short notice. The County of Middlesex took the lead in introducing military training into the county and municipal schools, the necessary funds being raised partly by a small grant from the War Office and partly by a subscription from the games fund, although in some cases parents and friends have contributed. The question is controversial, but England is now face to face with realities, and must realise that it takes time to build up a great, efficient organisation. In New Zealand and Australia training in military subjects is compulsory; and, should it be objected that this leads to militarism, the experience of Canada disproves the accusation. In a pamphlet signed by some of the most influential religious and educational authorities in the Dominion, and approved by the Canadian Government, it is stated that 'Some Canadians object to the introduction of drill into the schools because they think it develops a spirit of militarism; experience has proved that this view is incorrect. . . . Drill does more than develop a spirit of patriotism; it reveals to a boy his value as a citizen, and therefore his responsibilities for the performance of his duties as a citizen, not merely in the defence of his country, but upon the highest development of his country in all departments of national life.'

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6 *The Military Training of Youth in Schools.—A Review of the Systems of Training in the British Empire and in Various Foreign Countries.* *By* A. B. Wood, *M.Sc.*

The object of this paper is to supply a few undisputed facts which may serve as a basis for a scientific discussion on this important problem. Information has been collected from Canada, Australia, New Zealand, South Africa, Sweden, Norway, Switzerland, Italy, Germany, Austria, France, and U.S.A. As it is impossible in a brief abstract to mention all these countries, one or two cases only are given.

Australia.—In Australia all male inhabitants (except those specially exempted) are liable to military service in time of peace as well as in time of war. This principle of compulsory military training was made law in 1909, and came into operation in January 1911. The Defence Act provided compulsory military education for boys as follows:

Rank	Age	Service	Training
Junior Cadets .	12–14 years	2 years	Annually—90 hours
Senior Cadets .	14–18 years	4 years	Annually—4 whole days, 12 half-days, and 24 night drills
Citizen Forces (Militia)	18–26 years	8 years	Annually—In first 7 years drills equivalent to 16 whole days (including 8 'camps')

When in full operation this system involves the training of 100,000 Senior Cadets and 128,000 Militia (the population of Australia—excluding aboriginal natives—being about 4½ millions). The Junior Cadets (12-14) are given a general physical training, including swimming, first-aid, and miniature rifle-shooting. Senior Cadets (14-18) are subject to military discipline, and have regular military drills and rifle practice. On attaining the age of 18 the boys, if fit, are transferred to the Militia.

The expense of this training, as part of the educational system, is wholly included in the ordinary Education Budget.

Certain provision is made for 'religious objectors' and 'anti-militarists.' Reports by the Premiers of the various States of the Commonwealth give ample testimony to the success of the system.

New Zealand.—By the Defence Act of 1910-11, compulsory military training is provided for every male person between the ages of 14 and 35 years. Between the ages of 12 and 14 the boy receives a certain amount of physical training in the elementary school. At 14 he joins the Senior Cadet Corps, his subsequent training being now conducted on lines similar to the Australian system.

South Africa.—The Defence Act of 1912 provides that all boys between the ages of 13 and 17 years shall undergo a prescribed course of military training annually. The Act provides for compulsory military training 'only where it can be carried out efficiently,' *i.e.*, in urban and populous areas. In scattered districts Defence Rifle Associations are formed.

Sweden.—Compulsory military training was introduced into Swedish schools fifty years ago. Military exercises are given in all secondary schools, special emphasis being placed on rifle practice, at which 60 hours annually must be spent by every boy between the ages of 15 and 18 years inclusive. In elementary schools physical exercises are given regularly, but no rifle practice.

Norway.—The system here is similar to that of Sweden.

The value of this military training is estimated by referring to the reports of the respective Governments. All these reports describe the compulsory system of training as a great success, both from the point of view of the *boy* as an individual and the *nation* as a whole.

In the British 'System,' which is entirely voluntary, much excellent work is done by various voluntary organisations, such as Church Lads' Brigades, Miniature Rifle Clubs, School Cadet Corps, Boy Scouts, &c., and it becomes necessary to decide whether or not such a voluntary system could be improved by adopting a more centralised and systematic Government organisation of Cadet Corps on lines, say, similar to that of the Australian system.

Many interesting questions for discussion will immediately suggest themselves, *e.g.* : (1) Is the adoption of the compulsory system of training an indication of 'Militarism'?—To answer this question it is interesting to compare the cases of Germany and Switzerland or Australia.

(2) At what age should this training commence?—The 'stages of growth' (physical and mental) of a boy must necessarily be considered in this connection.

(3) 'Military Training' or 'Physical Exercises' in Elementary Schools?—The solutions of (1) and (2) answer this question automatically.

(4) With regard to boys who leave the elementary school without going on to the Secondary School, the same series of questions arise as in the discussion of the problem of Evening Continuation Schools.

FRIDAY, SEPTEMBER 10.

The following Reports and Papers were read :—

1. *Report on the Influence of School Books on Eyesight.*
See Reports, p. 234.

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2. *Report on Scholarships.*—See Reports, p. 238.

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3. *The Education of Girls for Professional Life.*

By Mrs. W. L. Courtney.

It is necessary to differentiate between :

I. Professions with a fixed course of training, for which a university education is a necessary preliminary (*e.g.*, medicine, teaching).
II. Professions for which girls cannot train until they are nineteen or over (*e.g.*, nursing, social work, higher grades of Civil Service).
III. Occupations which can be begun at an early age (*e.g.*, secretarial and clerical work, journalism, lower grades of Civil Service).

Class I. need not here be further considered because the school curriculum for these girls must necessarily be guided entirely by the requirements of the Universities.

Class II. includes two different types of professions. For some (*e.g.*, nursing) a university course is irrelevant; for others (*e.g.*, social work, Civil Service) it is eminently desirable, if the age at which wage-earning must be begun can be deferred until twenty-two to twenty-four. But the school curriculum will not need any special adaptation for either type. The nurse will be the better for a good general education, and would not in any case begin her vocational training at school. The social worker or aspirant to the Public Service, if she cannot afford the very desirable university course, will take her settlement, or other sociological, training from about the age of nineteen, and need not begin at school.

Class III. is the group immediately concerning us. Here there are two rival views : (1) That vocational training should begin at fifteen or sixteen either (*i*) during the last school year; (*ii*) at a special school or commercial college. (2) That vocational training should in no case begin before seventeen, and preferably should be deferred till eighteen. Those who hold this view advocate its non-inclusion in the curriculum of the secondary school.

The arguments in favour of (1) are (*a*) that it ensures the girl remaining longer at school; (*b*) that it thereby strengthens her character and improves her health; (*c*) that, while ensuring her these advantages, it turns her out equally proficient in technical subjects. This is frequently disputed.

The arguments against (1) are (*a*) that the time spent on vocational training is subtracted from the ordinary school hours, and therefore curtails general education; (*b*) that the girl so trained is not as proficient as the pupil of the special school.

The arguments in favour of (2) are obvious. It ensures better general education, and defers the vocational education to an age when the mind is more mature and the technical qualifications are therefore more rapidly and more effectively acquired.

The arguments against (2) are (*a*) that it defers the beginning of wage-earning to an age which many middle-class parents cannot afford; (*b*) that the employer prefers his assistants to begin young. This is again a very disputable point.

It is clear that the only person who certainly gains by the girl beginning young is the parent. The girl does not gain, for she feels the strain of work more severely, and chafes more against the long hours and confinement. And the employer's gain is illusive, for though the girl may be more amenable, she is less intelligent and attentive at sixteen than at eighteen, and in the long run probably of less use.

But if the girl is not to begin wage-earning work at sixteen, and is to wait till eighteen, where should she spend the years from sixteen to eighteen?

I answer, at school if possible, receiving a *good general education.* But if wage-earning at eighteen or earlier is indispensable, then from sixteen to seventeen at school, and from seventeen to seventeen and a half or eighteen at a secretarial or business training school, carefully selected. I do not believe in the possibility of getting more than the first rudiments of business training at school, because it is impossible to create there the business atmosphere. And though the 'hustle' of the crammer is as bad in its way as the ordinary school's absence of business atmosphere, there is something between the two, and that 'something' is what the ordinary business employer regards as indispensable. It

consists in a short training conducted, as far as possible, in classes pervaded by a business spirit, by persons who have been themselves in business and professional life and understand its requirements, as no educationist can understand them. It is a question of atmosphere, not of subjects. The better the general education, the shorter can be this period of special training. But it makes the pupil alert, business-like, and methodical, and is her best answer to the employer, who always seeks, if he can, a girl 'with previous experience,' thus placing serious difficulties in the path of the beginner. It will be very hard to persuade him that a girl, merely school-trained and not specially trained, has any equivalent at all to this 'previous experience.' And the more he can be persuaded to raise the standard of his requirements, the greater chance there is of raising generally the level of secretarial and clerical work, until it is worthy to rank as a profession, not an occupation, and of relegating to other employments the mass of ill-trained clerical workers, who at present degrade this and kindred branches of employment and bring down the rate of wages.

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4. *Women's Education.* *By* Miss Haldane.

We have to face special questions raised by war conditions, and must consider how to meet them. A new vista in employment has opened up for women. Of the enormous number of new openings that have arisen, some, of course, are temporary, but women will doubtless be more largely employed as earners in the future; (1) because of the shortage of men, (2) because in certain directions women's labour has proved as efficient as men's, and (3) because work will probably be plentiful but cheap after the War, and more individuals in the family will be required as wage-earners.

What preparations are we as educationists to make for the coming changes? We must above all realise that in our secondary education we have to prepare not only for the great profession of teaching, but for technical work of very varied sorts. We shall expect our women not only to become doctors, teachers, nurses, secretaries, &c., but also farmers, market gardeners, caterers, officials in factories, railways, &c., and we must see that these women do not go into their new occupation without the foundation of education which is essential if a man or woman is to carry on his or her work in a broad-minded way.

The danger at present is that girls are hurried through the training considered requisite before they have had time to think for themselves or find themselves as individuals. The danger is difficult to meet at this moment, but we must strain every nerve to prevent its becoming permanent. Whatever our economic condition, we should struggle against the fatal economy of curtailing the education of the nation, and should lay to heart the conclusions of Mr. Acland's Committee on Examinations in Secondary Schools. It would be most valuable if we could have a recognised stage in education (certainly not represented by any cram examination) which should be the gateway to the university on the one hand and the technical classes on the other.

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5. *The Education of Girls with reference to their Future Careers.* *By* Miss R. Oldham.

The War must of necessity aggravate what is already a serious condition of social life—the numerical preponderance of women over men. Another grave result will be the shortage of men in many occupations. The welfare of the community as a whole demands that we should in this time of social truce consider the measures that will best serve in the process of reconstruction. It is obvious that an increasing number of women must be denied the opportunities of wifehood and motherhood. How can such women best serve their purpose as useful citizens? Two reforms are vital: A free entry for women into all professions and callings from which they are not physically debarred, with a free way through these callings, and a raising of the status of the domestic worker or homemaker. The education of a girl suffers from the narrow sphere of choice that lies before her, and from the fact that, in such callings as are open

to her, she is for the most part relegated to a subordinate position and a lower scale of remuneration. Her intelligence shows her the injustice of artificial restrictions based on sex prejudice, and the anomaly of opening to her, *e.g.*, the profession of medicine while keeping that of law closed. Denied the rights of citizenship as she is, she has little incentive to high effort or to public spirit. It is hardly surprising that the outcome of such conditions should be, on the one hand, narrowness and irresponsibility, on the other bitter revolt against the prevailing social system. Even to-day, when the State has called upon women to volunteer for war service, there is a dangerous tendency to re-grade the work so as to reserve for men all that carries with it interest and responsibility. The time cannot be far distant when women will gain a larger participation in public life; it is one of the first duties of the teacher to prepare her girls for such participation by developing in them a sense of national responsibility.

In the second place a more liberal education is necessary for the girl who is to be the homemaker. In the opinion of many, it is in this sphere that woman performs her highest service to the State. If the foundations of national greatness are indeed set in the homes of the people, we should train with the utmost care the girls who will to a great extent make the home. We should seek to remove the stigma of inferiority that rests on girls whose tastes lie in the direction of domesticity and manual accomplishments. Such girls should be discovered early; to this end, every girl should, at some period of her school life, devote the greater part of one year to the domestic arts. This training should be supplementary to a broad general education, which, far from making a girl discontented with her lot, will do much to show her the importance of the service she is rendering to the nation.

The State could do much to give greater dignity to the career of the domestic worker by entrusting to women the control of certain branches of its departments, such as those that deal with maternity and child-welfare, or that demand special knowledge and experience possible only to women.

Finally, there is need for increased effort in every department of education. There must be among other advances a generous provision of Trade Schools to better the condition of the masses of women engaged in industry. What we need above all in England at the present time is to make our education a more systematic and careful preparation for the business of life.

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6. *Education of Girls with special reference to their Career—Education preparatory to Clerical Work.* By Miss E. A. Charlesworth.

The writer approached the subject from the point of view of one who has been engaged in clerical work for many years, and has been, as a member of the Executive Committee of the Association of Women Clerks and Secretaries, in touch with large numbers of women employed in all branches of such work.

As the outcome of this experience she has come to the conclusion that there are some general principles the inculcation of which is of greater importance and value as a preparation for work than any kind of special instruction. These may be summed up under the headings:

(1) Self-reliance and self-dependence. Determination to rely upon own qualifications and efforts, rather than upon influence of relatives and friends, in obtaining posts and making progress.

(2) Willingness to face the cost of living. Realisation that earnings must be sufficient to cover bad times as well as good, extraordinary as well as ordinary expenses.

(3) Appreciation of the place of the individual worker in the social economy, and of the influence of actions upon the welfare of fellow-workers.

Some kind of specialised instruction doubtless necessary. Consideration when this instruction should begin, what subjects form the best framework for it, and where and by whom it should be given.

Strong reasons why specialised instruction should not begin too early:

(*a*) Clerical work is of an abstract nature: it does not, like a craft, develop creative faculties and constructive powers. The meaning and value of the tasks

performed by a junior clerk are not obvious, and the work is not educative unless and until a broad foundation of general education has been laid.

(*b*) Without this broad foundation the work tends to have a narrowing influence upon the mind and a deteriorating effect upon the powers : the worker quickly arrives at a point beyond which no further development seems possible.

Suggestions as to subjects which should be introduced in specialised instruction : Elementary economics, principles of accountancy and of record-keeping, geography on modern principles, reading of good journals and newspapers.

As to where instruction should be given, it is clear that the general principles set out above could only be inculcated in a school where the tone and discipline were good; the secondary school is undoubtedly the best place for girls to receive both general and special instruction.

SATURDAY, SEPTEMBER 11.

The following Papers were read :—

1. *The Relation of Education to Industry.*

By Right Hon. Sir WILLIAM MATHER, *M.Inst.C.E., LL.D.*

The question is of the highest importance, and, viewed in the largest sense of the words, the relationship is as close as that of the soul to the body, for it is the spirit which inspires, directs, and ennobles the bodily activities.

At the Meeting of the British Association in Manchester in 1887 the writer dealt with another fundamental aspect of the same question in discussing the subject of manual training as a main feature of national education. The President of the Association, Sir H. E. Roscoe, remarked in his presidential Address on that occasion that if the country is to maintain its industrial and commercial supremacy it can only be accomplished by a reconsideration of the whole question of education on new lines embracing all the people, and that a statesman who could effectively achieve this would earn the gratitude of generations yet to come. Succeeding Presidents like Sir Norman Lockyer and Sir William Ramsay enforced this view, but the statesman has yet to appear. A much more liberal provision of the means and opportunities of education for all classes is essential to the well-being of the nation. At the time of the former meeting of the Association in Manchester our national education was miserably inadequate for the highest efficiency of work and service. Even the Act of 1870, designed to provide in some measure the means of education for the masses of the people, failed of its purpose, and it was not until 1889 that Parliament made any attempt to provide the means of any satisfactory secondary and technical education, with the consequence that nations such as Germany and the United States, where education had greatly developed, reaped to a far greater extent the fruits of scientific discovery. During the period marked by the achievements of Faraday, England produced some of the most eminent scientists of the world ; yet it was in foreign countries in which the spirit of education had long before penetrated the lives of the people that the new revelations of scientific discovery were most successfully applied to the common needs of life. The industrial and commercial results achieved thereby at last stirred our Government to send out the Royal Commission of 1882 to investigate the causes and to inquire into the facilities for secondary and technical education existing in foreign countries. The Report of the inquiry published in 1884 of the conditions of education in Europe and in the United States, in which country the writer had spent eight months of careful investigation, created widespread alarm in the United Kingdom and in other parts of the Empire. No immediate action ensued therefrom until, as a result of the persistent efforts of a few resolute men, an Act was passed for the advancement of technical education at the very close of the session of 1889, to be followed by the Act of 1890 which appropriated the proceeds of the 'whisky and beer' tax to the support of technical education. The large manufacturing centres took

up the Act with avidity, with the result that many fine institutions—that in Manchester chief among the number—were erected in many parts of the United Kingdom. It was quickly seen, however, that no system of thorough technical education can be carried out satisfactorily where secondary education on an adequate scale is a missing link; and so in 1902, on a reorganisation of elementary education, whereby much larger powers were given to local authorities, secondary education came within their purview, and secondary schools which were unrecognised and unaided in 1887 became a constituent element in the full provision of education. In the development of the means of technical instruction, especially in evening schools, the City and Guilds of London Institute, founded in 1879, has played an important part as an examining body, at one time spending large sums in aid of technical training; and there were also other examining and co-ordinating bodies such as the Union of Lancashire and Cheshire Institutes. The value of these voluntary agencies is not to be lightly esteemed. The progress of university education has shown within the period covered a marked advance in the facilities available, not only with respect to the higher branches of learning but also in the application of science to industry. We are still, however, far below the standard demanded for successful competition with the more advanced nations. There should be no false economy such as is implied in the reduction of the public grants in aid of any form of education. Much fuller educational provision is needed beyond the age of fourteen. The result of this neglect is seen in wasted lives and effort, and should receive the serious consideration of a specially constituted body of industrial and educational experts, especially in view of the crisis that now confronts us. To meet this moral and material waste of the children there should be a 'save the children' tax, and, in addition, in the highest interests of the nation, the poorest children require a system of voluntary service in aid of the public authorities so as to ensure their physical fitness. We must make good the ravages of this dreadful war. Much improvement is needed in the quality of the teaching power. The spiritual and moral side of education should be considered as well as the physical. The present method of administration of national education is not the most efficient either for initiation or control. It hinders the development of local initiative and prevents enlightened progress. A small salaried Council of the best men in the country, regardless of party, would ensure continuity of principles and progressive methods. The local authorities would undertake larger responsibilities and secure higher educational efficiency. Measures would be promoted establishing means of education essential to the well-being of the industrial classes, and to a more generous view of the relations which should exist between employer and employed, with the consequent avoidance of industrial strife with its waste of capital and energy and the untold misery of women and children. We must ensure industrial peace and a higher industrial relationship. Our enjoyment of political freedom and our sense of individual responsibility make possible a favourable solution. An equal education of the moral and spiritual faculties, as of the intellectual, must be ensured, so as to avoid the horrors which this gigantic War has revealed. The altruistic tendencies in human nature are suppressed in the German scheme of education, and self-aggrandisement and self-glorification become the sole aim. Our destiny is the reverse of all this. 'Live and let live' is our maxim. Let the fullest educational opportunities be given to all classes. The outstanding menace to our position as an industrial nation lies in the chronic separation of Capital and Labour. Their highest interests are the same. A true education will blend them into one whole—to a real co-operation in the fruits of industry.

(Appendices were attached to the paper, giving important illustrative statistics.)

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2. *Education and Industry.* *By* Principal J. C. M. Garnett.

The unshaded portion of the diagram (page 757) is concerned with 'full-time' education; that is, with schools and classes meeting in the day-time and occupying all the working hours of those by whom they are attended. The central singly shaded area relates to part-time classes; classes meeting either

in the day or in the evening, and intended for persons whose industrial employment occupies the greater part of their time. The doubly shaded region on the right of the diagram corresponds to those later years of industrial practice when a man has ceased to attend organised courses of study bearing upon his trade or profession, but when he may nevertheless be studying vocational subjects privately, or be attending such non-vocational courses as those of the Workers' Educational Association.

The diagram (see next page) represents neither what is nor what might be under ideal conditions, but what might be made out of what is with the maximum of advantage for the effort expended on the change.

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3. *Education in its relation to Industry.* By JAMES GRAHAM.

The relation between education and industry may be considered by following

(*a*) The career of the elementary school boy,
(*b*) The career of the secondary school boy,

and discussing reforms that are needed to bring education and industry into still closer relationship.

The Elementary School Boy in School.—The success of industry depends on the efficiency of all ranks of those engaged in it. The production of a capable industrial army is primarily a question of education, and the relation between education and industry, therefore, begins in the elementary school.

At present the country is not getting adequate value for the money spent on elementary education due to

(i) the too short school period of the average boy,
(ii) the want of a closer relationship between the school curriculum and the needs of life.

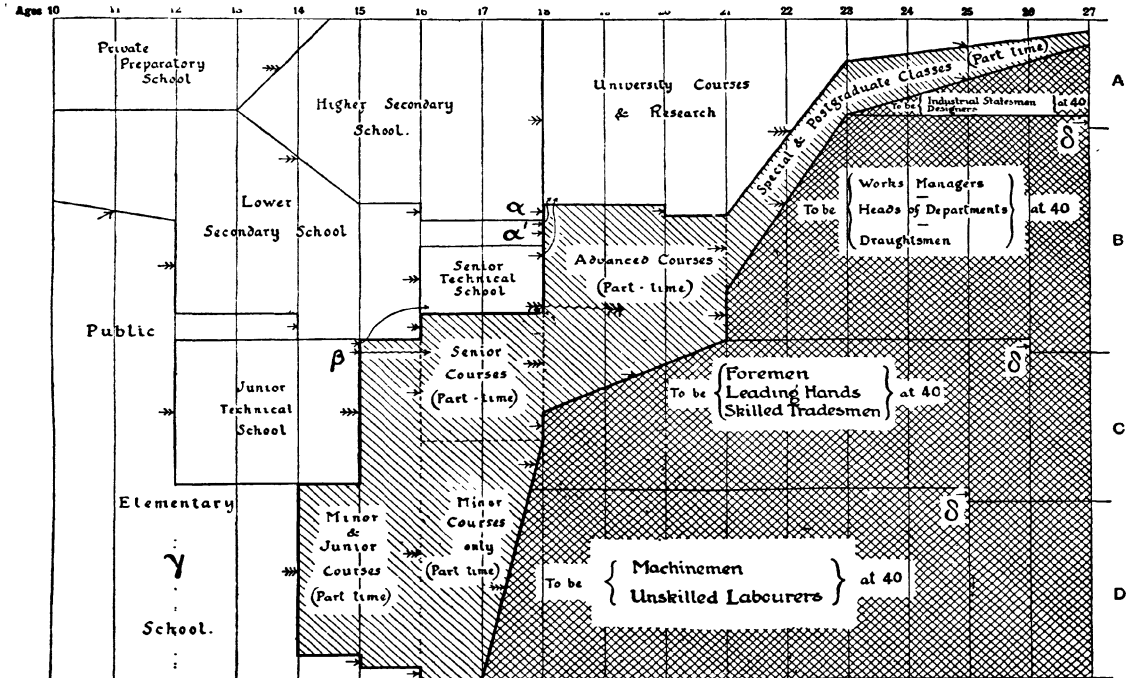
It is essential that the school life of the elementary school pupil should be extended. The minimum leaving age should be fourteen years and the children should leave only at the end of the school term in which the leaving age is reached An extended school life would allow of the organisation of special courses of instruction for the older boys which should prove extremely valuable in preparing them for the work they will undertake on leaving school. While meeting the strong demand for industrial or vocational education, it must be remembered that the purpose of elementary education is not to prepare for particular trades, but to develop all the boy's faculties so that he may be prepared to enter any walk of life.

The all-round general education of the boy, and not the production of a wage-earning machine, must be the first consideration. There must be no attempt to teach a specific trade, but 'learning by doing' must take the place of book learning to produce the type of boy required by the workshop and factory.

For the senior boys in the elementary schools approximately one-third of the school time should be devoted to English subjects, one-third to mathematics and technical drawing, and one-third to experimental and practical work in the school workshops, the scheme of instruction being arranged with the intention of securing an all-round development of the boy's faculties in order that when the boy is ready to commence work he may possess not only a general grip of the principles that underlie trades in general, but intelligence, reasoning power, and adaptability. In this way a more adequate return for the money spent on elementary education would be secured and the gain to industry and to the nation would be enormous.

The Elementary School Boy in the Works.—The problem of the boy from fourteen to eighteen years of age involves a closer relationship between education and industry. Opportunities must be provided for the boy to lay the foundation of a livelihood which in the main will persist through life. At the same time it must be remembered that the boy is a future citizen as well as a potential wage-earner, and facilities are required not only to enable him to understand the occupation he has entered, but also to enable him to understand his duties as a

EDUCATION AND INDUSTRY.—Diagram illustrating proposed modification of present organisation.



HORIZONTAL SCALE. The spaces between adjacent vertical lines represent one year.
VERTICAL SCALE. The vertical scale increases from the bottom of the diagram to the top The intercept made on any ordinate by the enclosed area which corresponds to any course varies with (but not strictly in proportion to) the number of students of the corresponding age who should be following the course in question.

⇉ } indicates that { the great majority of the / a constant supply of systematically selected / a few exceptional } persons leaving the course which corresponds to the area in which the arrowhead lies should proceed to the course towards which it points.

citizen. He must have opportunities for training which will fit him for manhood and for his place in the nation.

The Workshop and the Technical School.—In the highly organised workshops of the present time it is impossible for the boy to learn the whole of his trade. The employer is no longer able to educate his apprentice or young worker, and the schoolmaster, therefore, must come in to do a part of the work. When the boy enters the workshop his education is far from complete. Continued education applicable to his chosen trade must be given, and it is in this connection that the technical schools of the country, working in close co-operation with the workshops, should fulfil their real function.

To expect the young worker to get the necessary technical education by attending evening school for three or four evenings a week after he has done a full day's work in the workshop is indefensible, and voluntary schemes of co-operation between employers and Education Authorities are ineffective. Only a small proportion of the young workers of the country attend evening schools in spite of the inducements offered and of the encouragement given, and the effect of evening education on the nation as a whole is very slight.

The only rational and effective way to train the rising generation of skilled workmen after leaving the elementary schools is to have half-time in the workshops and half-time in the technical schools, or at least some approximation to this, between the ages of fourteen and eighteen. Young workmen must be enabled to attend suitable courses of instruction for periods of suitable length within the normal working day.

In this respect England suffers by comparison with other nations. A further limitation of juvenile labour is urgent, and it must be made the duty of the employers to allow young persons under eighteen to attend courses of technical and general instruction at certain hours of the day-time when they are not too tired bodily and mentally to profit from the instruction.

Special Opportunities for proved Ability. Such a scheme would result in an army of skilled workmen; but no potential talent must be lost. There must be facilities for young workmen of brains and capacity to secure the education and training required of those who fill the highest posts in industry. Special provision must be made to enable young workers of proved ability to attend day courses at the university for two or three years in order that they may understand the application of scientific methods in the development of industry. In this connection technological scholarships to enable selected young workers to follow day courses in science and technology at the university have proved extremely useful.

The Secondary School Boy in the School.—There has been during recent years much discussion regarding the nature of the curriculum which should pertain in secondary schools, and now we are approaching well-balanced schemes of study which are likely to produce harmonious development of the faculties of the boy. The work of a secondary school should not be guided by the desire to qualify a few boys at the top to win university scholarships. On the other hand, the danger of undue importance being placed on the vocational side and a secondary school becoming a day technical school at the top must be avoided. There is no inherent opposition between general education and life purpose; it is possible to have a sound core of general education throughout and at the same time to give due attention to the requirements of the future occupations of the boys.

As in the elementary school, so in the secondary school, there must be no pure trade instruction—no attempt to teach a specific trade. While at the secondary school the boy must receive a sound general education with such preparatory vocational training as will tend to produce a free and inventive mind, ready to attack the technical problems which will face him when he actually enters industry.

Secondary School Pupils beyond the School Age.—England fails in the industrial world where trained intelligence of the highest order is the deciding factor, and in the future education must assist industry by providing expert helpers and capable leaders. For these no education can be considered too good—no training too high. Our future leaders of industry must be equipped for competition on equal terms with the highly trained young men of other nationalities. A sound education in the secondary schools, followed by thorough training in the technical

and science departments of the university, combined with adequate experience in the workshop or factory, is required.

Safeguards must be taken to prevent the training being too academic. In addition to the intellectual and technical training, there must be opportunities for the student to obtain first-hand knowledge of the particular industry in which he is interested A year's experience in the workshop may precede the student's entrance to the university, in which connection a system of 'deferred scholarships' from the secondary schools to the university for boys who intend to enter industry would be useful, or the 'sandwich system' of training may be adopted, in which case the youth on leaving the secondary school would enter on a course of training which each year is carried on partly in the university and partly in the workshop.

Equality of Opportunity for Capacity.—Industry is now experiencing the lack of expert technical helpers, and the present crisis should bring the nation to recognise how essential it is to utilise to the full native brain power in whatever rank it is found. British talent is not inferior to that of other nations, but technically trained talent will naturally dominate untrained talent in industrial enterprise, and it is for us to see that native talent has at home facilities for specialised training not less favourable than those enjoyed by foreigners in their country. England must be the land of 'opportunity and the sieve.' There must be careful selection of capacity, with ample facilities for specialised study, to produce men of intellectual power, combined with high technical training. Our present system which allows mediocrity with pecuniary means to secure high training and denies such training to natural high capacity without pecuniary means is wasteful. High intellectual endowment is a natural asset, and the State should adopt methods to realise this asset. There are required

(*a*) an extended system of scholarships,
(*b*) grants-in-aid or maintenance allowances to enable suitable students to continue their studies,
(*c*) greater endowment of research.

Research is intimately connected with manufacturing progress. Without highly trained men engaged in experimental work there can be no development of industry, and unless there is development there must be stagnation and decay. The astounding apathy with which English firms are accustomed to view the highly trained expert in industry must give way to a full appreciation of the value of trained intellect if British industry is to flourish.

Education and Industry a Partnership.—Great gaps are now being made in the ranks of skilled workers of every grade in industry, in commerce, and in the professions. As a nation we shall have to make good the wealth which is lost. The War will be followed by keen competition between the brains of the various nations, and England should prepare along thorough and adequate lines for that struggle. It is by an alliance between the educational institutions and the workshops of England and close co-operation between the employers and the Education Authorities that success will be attained. If the proper relationship between education and industry is secured, there will arise in England an industrial army with trained leaders capable of maintaining our industrial supremacy.

Papers on the same subject were also contributed by :—

4. Professor H. E. Armstrong, *F.R.S.*
5. A. P. M. Fleming.
6. J. G. Pearce.
7. Dr. W. Cramp.

SECTION M.—AGRICULTURE.

PRESIDENT OF THE SECTION: R. H. REW, C.B.

WEDNESDAY, SEPTEMBER 8.

The President delivered the following Address :—

Farming and Food Supplies in Time of War.

AGRICULTURE is the antithesis of warfare; farming is pre-eminently a peaceful avocation, and farmers are essentially men of peace. The husbandman is not easily disturbed by war's alarms, and his intimate association with the placid and inevitable processes of Nature engenders a calmness of spirit which is unshaken by catastrophe. Many stories illustrative of this attitude of mind come to us from the battlefields The complete detachment of the fighting men from the rest of the community which was usual up to quite recent times is impossible in these days when in almost every country the army is not a class but the nation. It is inconceivable now that a war could rage of which it could be said, as has been said of our Civil War : 'Excepting those who were directly engaged in the struggle, men seemed to follow their ordinary business and their accustomed pursuits. The story that a crowd of country gentlemen followed the hounds across Marston Moor, between the two armies drawn up in hostile array, may not be true; but it illustrates the temper of a large proportion of the inhabitants.'[1] But, while farmers and peasants within the range of the guns cannot now ignore the fighting, they have repeatedly demonstrated their invincible determination that the madness of mankind shall not interrupt the calm sanity of the ordered cultivation of the soil. Of a district in the Argonne, a correspondent, writing in April last, said : 'The spring seed has already been sown or is being sown, sometimes indifferently, under shell-fire, right up to the edge of the trenches.'[2] A story was told of a farmer in Flanders looking over the parapet of a trench and demanding of an indignant British officer whether any of his men had stolen his pig. On receiving a suitable reply, he observed that he had already asked the French, who also denied all knowledge of the missing animal, so that he supposed it must be those condemned Germans, whom he forthwith proceeded to interview. Such a sublime sense of values, such absorption in the things that matter, such contempt for the senseless proceedings of warfare, are only possible to the agriculturist. The quarrels of mankind are transient, the processes of Nature are eternal. One thinks of Matthew Arnold's lines :

> The East bowed low before the blast
> In patient deep disdain;
> She let the legions thunder past,
> And plunged in thought again.

But, while the farmer is by instinct a pacifist, he is also, in a cause which rouses him, a doughty fighter. In that same Civil War to which so many were indifferent, the farmers of East Anglia, under Cromwell, changed the course of English history; and the thoroughness with which they turned their plough-

[1] Prothero, *English Farming, Past and Present*, p. 104.
[2] *Westminster Gazette*, April 30, 1915.

shares into swords is demonstrated by the fact that when they took to soldiering they put the nation for the first and only time under what is now termed militarism; that is, government controlled by the Army. In the last battle fought on English soil the yeomen and peasants of the West Country proved, amid the butchery of Sedgemoor, that bucolic lethargy can be roused to desperate courage. Indeed, through all our island story, since the English yeomen first broke the power of mediæval chivalry and established the supremacy of infantry in modern warfare, it has been from the rural districts that the nation has drawn its military strength. Even in the present war, when the armies of the Empire have been drawn from all classes of the community, the old county regiments and the yeomanry squadrons with their roots in the countryside have proved once more that the peaceful rustic is as undismayed on the field of battle as on the fields of peace.

It is, however, in his pacific rather than in his belligerent aspect that the British farmer now claims our attention, and, before considering the position of farming in the present war, we may briefly glance at its position when a century ago the nation was similarly engaged in a vital struggle.

From February 1793 until 1815, with two brief intervals, we were at war, and the conflict embraced not only practically all Europe but America as well. The latter half of the eighteenth century had witnessed a revolution of British agriculture. The work of Jethro Tull, 'Turnip' Townshend, Robert Bakewell, and their disciples, had established the principles of modern farming. Coke of Holkham had begun his missionary work; Arthur Young was preaching the gospel of progress; and in 1803 Humphry Davy delivered his epoch-making lectures on agricultural chemistry. Common-field cultivation, with all its hindrances to progress, was rapidly being extinguished, accelerated by the General Inclosure Act of 1801. A general idea of the state of agriculture may be obtained from the estimates made by W. T. Comber of the area in England and Wales under different crops in 1808. There were then no official returns, which, indeed, were not started until 1866; but these estimates have been generally accepted as approximately accurate and are at any rate the nearest approach we have to definite information.

I give for comparison the figures from the agricultural returns of 1914, which approximately correspond to those of the earlier date:

	1808	1914
	Acres	Acres
Wheat	3,160,000	1,807,498
Barley and rye	861,000	1,558,670
Oats and beans	2,872,000	2,223,642
Clover, rye-grass, &c.	1,149,000	2,558,735
Roots and cabbages cultivated by the plough	1,150,000	2,077,487
Fallow	2,297,000	340,737
Hop grounds	36,000	36,661
Land depastured by cattle	17,479,000	16,115,750

The returns in 1914 comprise a larger variety of crops than were cultivated in 1808. Potatoes, for instance, were then only just beginning to be grown as a field-crop, and I have included them, together with Kohl-rabi and rape, among 'roots and cabbages.'

The population of England and Wales in 1801 was 8,892,536, so that there were 35½ acres under wheat for every hundred inhabitants. In 1914 the population was 37,302,983, and for every hundred inhabitants there were 5 acres under wheat.

The yield of wheat during the twenty years ending 1795 was estimated at 3 qrs. per acre[3]; in 1914 it was 4 qrs. per acre. The quantity of home-grown wheat per head of population was therefore 8½ bushels in 1808, and 1½ bushels

[3] Report of Select Committee on the means of promoting the cultivation and improvement of the waste, uninclosed and unproductive lands of the Kingdom, 1795.

in 1914. Nevertheless, even at that time, the country was not self-supporting in breadstuffs. In 1810, 1,305,000 qrs. of wheat and 473,000 cwt. of flour were imported. The average annual imports of wheat from 1801 to 1810 were 601,000 qrs., and from 1811 to 1820 458,000 qrs. Up to the last decade of the eighteenth century England was an exporting rather than an importing country, and bounties on exports were offered when prices were low, from 1689 to 1814, though none were, in fact, paid after 1792.

During the war period we are considering, the annual average price of wheat ranged from 49*s.* 3*d.* per qr. in 1793 to 126*s.* 6*d.* per qr. in 1812; the real price in the latter year, owing to the depreciation of the currency, being not more than 100*s.* In 1814 the nominal price was 74*s.* 4*d.* and the real price not more than 54*s.* per qr.[4] The extent to which these high and widely varying prices were affected by the European war has been the subject of controversy. As we mainly depended on the Continent for any addition to our own resources, the diminished production during the earlier years in the Netherlands, Germany, and Italy, and in the later years of the war in Russia, Poland, Prussia, Saxony, and the Peninsula, reduced possible supplies. At the same time the rates of freight and insurance, especially in the later years of the war, increased very considerably. Tooke mentions a freight of 30*l.* per ton on hemp from St. Petersburg in 1809. On the other hand, a powerful impetus was given to home production, which was stimulated by Government action and private enterprise. Inclosure was encouraged by the General Inclosure Act of 1801, and 1,934 Inclosure Acts were passed from 1793 to 1815. The schemes for increasing and conserving food supplies were various. The Board of Agriculture, for example, offered prizes of 50, 30, and 20 guineas respectively to the persons who in the spring of 1805 cultivated the greatest number of acres—not less than 20—of spring wheat.[5] In 1795 a Select Committee recommended that bounties should be granted to encourage the cultivation of potatoes on 'lands at present lying waste, uncultivated, or unproductive,' and that means should at once be adopted to add at least 150,000 and perhaps 300,000 acres to the land under cultivation 'as the only effectual means of preventing that importation of corn, and disadvantages therefrom, by which this country has already so deeply suffered.' Another view of importation is presented by Tooke, who, in a discussion of the effect of the war, says: 'Although the war cannot have been said to have operated upon the supply of agricultural produce of our own growth and other native commodities, sufficiently to outweigh the circumstances favourable to reproduction, it operated most powerfully in increasing the cost of production and in obstructing the supply of such commodities as we stood in need of from abroad. It is therefore to war chiefly as affecting the cost of production and diminishing the supply, by obstructions to importation, at a time when, by a succession of unfavourable seasons, our own produce became inadequate to the average consumption, that any considerable proportion of the range of high prices is to be attributed.'[6]

The main cause of high prices and scarcity was the failure of the harvests. Mr. Prothero thus analyses the wheat harvests of the twenty-two years 1793–1814: 'Fourteen were deficient; in seven out of the fourteen the crops failed to a remarkable extent, namely in 1795, 1799, 1800, 1809, 1810, 1811, 1812. Six produced an average yield. Only two, 1796 and 1813, were abundant; but the latter was long regarded as the best within living memory.'[7]

It appears paradoxical, but in a sense it is true, to say that the scarcity of wheat in certain years arose from the fact that the country was too largely dependent on its own crop. The risk of a bad harvest in a climate such as that of the British Isles must always be serious, and by the fortune of war this risk between 1793 and 1814 turned out to be very high. When supplies are drawn from the four quarters of the globe, it is evident that the risk of a shortage in time of peace is greatly reduced. Whether in a great war it is preferable to be more dependent on the sea than on the season is debatable.

[4] Porter's *Progress of the Nation*, by F. W. Hirst, p. 183.
[5] *Annals of Agriculture*, 1805.
[6] *History of Prices*, ed. 1838, vol. i. p. 116.
[7] *English Farming, Past and Present*, p. 269.

In comparison with wars for national existence, such as that against Napoleon and in a still sterner sense that in which we are now engaged, other conflicts appear insignificant. The Crimean War, however, did affect our food supplies and had a reflex action on British agriculture. The cessation of imports from Russia caused a rise in the price of corn. The average price of wheat rose to 72*s.* 5*d.* per qr. in 1854, 74*s.* 8*d.* in 1855, and 69*s.* 2*d.* in 1856. Only once before (in 1839) during the previous thirty-five years had it risen above 70*s.* There were then no agricultural returns, but the estimates of Lawes, which were generally accepted, put the area under wheat at a little more than 4,000,000 acres, a higher figure than has been suggested for any other period. It is, indeed, highly probable that the Crimean War marked the maximum of wheat cultivation in this country. It was a time of great agricultural activity and of rapid progress. To their astonishment, farmers had found, after an interval of panic, that the Repeal of the Corn Laws had not obliterated British agriculture and that even the price of wheat was not invariably lower than it had often been before 1846. Caird had preached 'High Farming' in 1848 and found many disciples, capital was poured into the land, and the high prices of the Crimean period stimulated enterprise and restored confidence in agriculture.

To generalise very roughly, it may be said that while the Napoleonic wars were followed by the deepest depression in agriculture, the Crimean War was followed by a heyday of agricultural prosperity which lasted for over twenty years What the agricultural sequel to the present war may be, I leave to others to estimate, and I turn to consider briefly some of its effects on British farming up to the present time.

Harvest had just begun when war broke out on August 4: indeed, in the earlier districts a good deal of corn was already cut The harvest of 1914 was, in fact, with the exception of that of 1911, the earliest of recent years, as it was also one of the most quickly gathered. The agricultural situation may perhaps be concisely shown by giving the returns of the crops then in hand, *i.e.*, in course of gathering or in the ground, with the numbers of live stock as returned on farms in the previous June The figures are for the United Kingdom, and I add the average for the preceding ten years for comparison :

	1914	Average 1904-13
	Qrs.	Qrs.
Wheat	7,804,000	7,094,000
Barley	8,066,000	7,965,000
Oats	20,664,000	21,564,000
Beans	1,120,000	1,059,000
Peas	374,000	525,000
	Tons	Tons
Potatoes	7,476,000	6,592,000
Turnips and swedes	24,196,000	26,901,000
Mangold	9,522,000	9,934,000
Hay	12,403,000	14,148,000
	Cwts.	Cwts.
Hops	507,000	354,000
	No.	No.
Cattle	12,185,000	11,756,000
Sheep	27,964,000	29,882,000
Pigs	3,953,000	3,805,000
Horses	1,851,000	2,059,000

Farmers had thus rather more than their usual supplies of nearly every crop, the chief deficiencies being in peas, roots, and hay. The shortage of the hay-crop was, however, in some measure made up by the large stocks left from the unusually heavy crop of 1913. It was fortunate from the food-supply point

of view that two of the most plentiful crops were wheat and potatoes. The head of cattle was very satisfactory, being the largest on record, and pigs were well above average. Sheep, always apt to fluctuate in numbers, were much below average, the total being the smallest since 1882 with the exception of 1913.

On the whole, it was a good year agriculturally, and the supply of home-grown produce at the beginning of the war was bountiful. Nature at any rate had provided for us more generously than we had a right to expect.

At first it appeared as if farmers were likely to be sufferers rather than gainers by the war. Prices of feeding-stuffs, especially linseed and cotton-cakes, maize-meal, rice-meal, and barley-meal, rose at once, recruiting affected the labour supply, and difficulties arose in the distribution of produce by rail. With one or two exceptions, such as oats, the prices of farm produce showed but little rise for three or four months after the war began. Wheat rose about 10 per cent., barley remained about normal, cattle by November had not risen more than 3 per cent., sheep and veal-calves showed no rise until December, while poultry was actually cheaper than usual, though eggs rose considerably. Butter rose slightly, and cheese remained about normal. Up to nearly the end of the year, in fact, it may be said generally that British farm produce made very little more money than usual.

Meanwhile the nation began to take a keen interest in the agricultural resources of the country, and farming became the object of general solicitude. We started with great energy to improvise, in truly British fashion, the means of facing the supreme crisis of our fate, but the elementary fact at once became obvious that it is impossible to improvise food. The main farm-crops take an unreasonably long time to grow, even if the land is prepared for them, and a sudden extension of the area under cultivation is not a simple proposition. It was freely pointed out—with undeniable truth—that our agricultural system had not been arranged to meet the conditions of a great European war, and many suggestions were made to meet the emergency. Some of these suggestions involved intervention by legislative or administrative action. It was decided that any attempt violently to divert the course of farming from its normal channels would probably not result in an increased total production from the land. The Agricultural Consultative Committee, appointed by the President of the Board of Agriculture on August 10, issued some excellent advice to farmers as to their general line of policy and the best means by which they could serve the nation, and this was supplemented by the Board and by the agricultural colleges and local organisations throughout the country. No less than thirty special leaflets were issued by the Board, but, while it may, I think, fairly be claimed that all the recommendations made officially were sound and reasonable, I should be the last to aver that farmers were universally guided by them. They do not accept official action effusively :

> 'Unkempt about those hedges blows
> An English unofficial rose,'

and official plants do not flourish naturally in farm hedgerows. It was, however, fairly evident that patriotism would suggest an effort to obtain the maximum production from the land, and there were good reasons to think that self-interest would indicate the same course. It must be admitted, however, that during the autumn the lure of self-interest was not very apparent. Food-prices, however, at the end of the year began to rise rapidly. English wheat in December was 25 per cent. above the July level, in January 45 per cent., in February and March 60 per cent., and in May 80 per cent. Imported wheat generally rose to a still greater extent, prices in May standing for No. 2 North Manitoba 95 per cent., and No. 2 Hard Winter 90 per cent. above July level. The greater rise in imported wheat may be noted as vindicating farmers against the charge which was made against them of unreasonably withholding their wheat from the market. Cattle and sheep rose more slowly, but in March prices of both had risen by 20 per cent., and in May and June cattle had risen by about 40 per cent. Butter rose by about 20 per cent. and cheese by about 40 per cent. Milk rose little through the winter, but when summer contracts were made prices remained generally at the winter level.

British agriculture, like the British Isles, is a comparatively small affair,

geographically. The 47 million acres which it occupies, compared with the 80 million acres of Germany or the 90 million acres of France, and still more with the 290 million acres of the United States, represent an area which may be termed manageable and about which one might expect to generalise without much difficulty. But, in fact, generalisation is impossible. Even on the 27 million acres of farm land in England and Wales there is probably more diversity to the square mile than in any country on earth. The variations in local conditions, class of farming, and status of occupier preclude the possibility of making any general statement without elaborate qualifications. Thus whatever one might say as to the effects of the war on agriculture would be certain to be inaccurate in some districts and as regards some farmers.

There are three main agricultural groups, corn-growing, grazing, and dairying. They overlap and intermingle indefinitely, and there are other important groups, such as fruit-growing, vegetable-growing, hop-growing, &c., which represent a very large share of the enterprise and capital engaged on the land. The receipts of the corn-growing farmer, generally speaking, were substantially increased. Probably about 50 per cent. of the wheat-crop had been sold before prices rose above 40*s.* per quarter, and there was very little left on the farms when they reached their maximum in May. Oats rose rather more quickly, but did not reach so high a level, relatively, as wheat. Barley—owing perhaps to enforced and voluntary temperance—never made exceptional prices, and in fact the best malting barleys were of rather less than average value. There is no doubt, however, that farmers who depended mainly on corn-growing found an exceptionally good market for their crops and made substantial profits. Farmers who depended mainly on stock were less generally fortunate, although stock were at a fairly high level of price when the war began. Sheep for some time showed no signs of getting dearer, but in the spring prices rose substantially, and a good demand for wool—which in one or two cases touched 2*s.* per lb.—made the flockmasters' returns on the whole very satisfactory. Cattle followed much the same course; stores were dear, but by the time fat stock came out of the yards or off the grass prices had risen to a very remunerative level. The large demands on imported supplies of meat for the British and French armies occasioned a distinct shortage for the civil population, but this was relieved by a reduced demand, so that the effect upon prices of native beef and mutton was not so great as might have been expected. The influence of a rise of price upon demand is more marked in the case of meat than in that of bread. While there has been a distinct reduction in the consumption of meat, there is no evidence of a reduced consumption of bread.

Dairy farmers generally found themselves in difficulties. Prices of butter and cheese increased but slightly, and milk remained for a considerable period almost unchanged. The rise in the prices of feeding-stuffs and the loss of milkers aggravated their troubles. An actual instance of the position in February as affecting a fairly typical two-hundred-acre farm may be quoted. It had thirty milch cows, producing about 16,500 gallons per annum. The cake bill showed an advance of fifty per cent., and wages had risen twelve per cent. It was calculated that the extra cost was 1 3*d.* per gallon of milk. Later the prices of milk, butter, and cheese rose, but on the whole it cannot be said that dairy farmers generally made exceptional profits.

While it is certain that the gross receipts by farmers were substantially increased, it is very difficult to estimate what the net pecuniary gain to agriculture has been. It can only be said generally that while some have made substantial profits, which probably were in very few cases excessive, many others have on balance (after allowing for extra cost) done no better financially, and some perhaps even worse, than in an average year of peace. With regard to one item of extra cost, that of labour, it is possible to make an approximate estimate. Agricultural labourers were among the first to respond to the call for the new armies, and, up to the end of January, fifteen per cent. had joined the forces of the Crown. This considerable depletion of labour was not acutely felt by farmers during the winter, but during the spring and summer serious difficulty was experienced and many devices were suggested—some of which were adopted—for meeting it. Naturally the wages of those agricultural labourers who were left rose, the rise varying in different districts but being

generally from 1*s.* 6*d.* to 3*s.* per week. Owing to the rise in the price of commodities, this increase of wages cannot be regarded as a profit to the labourers, but it is, of course, an outlay by farmers, which in England and Wales may be reckoned as amounting to an aggregate of about 2,000,000*l.*

This country has never suffered from a dearth of agricultural advisers, and in such a time as the present, when everyone is anxious to help the country, it is natural that they should be unusually plentiful. Advice was freely offered both to the Government how to deal with farmers and to farmers how to deal with the land. Whether in consequence of advice or in spite of it, it may fairly be said that farmers throughout the United Kingdom have done their duty. They have met their difficulties doggedly and have shown an appreciation of the situation which does credit to their intelligence. It was not easy last autumn, when farmers had to lay their plans for the agricultural year, to forecast the future. We were all optimists then, and many thought that the war might be over before the crops then being planted were reaped. It was clear, however, that the national interest lay in maintaining and, so far as possible, increasing the produce of the land. In the quiet, determined way which is characteristic of them, farmers devoted themselves to the task, and the returns recently issued give the measure of their achievement. They have added twenty-two per cent. to the acreage of wheat and seven per cent. to the acreage of oats, and they have kept the area of potatoes up to the high and sufficient level of the previous year. These are the three most important crops. They have also not only maintained the stock of cattle, which was the largest on record, but, in spite of unfavourable conditions and a bad lambing season, they have increased the stock of sheep. In view of these facts, I venture to say that British and Irish farmers have shown both patriotism and intelligence, and may fairly claim to have contributed their share to the national effort.

The share of British agriculture in the food supply of the nation is more considerable than is sometimes realised. When I last had the honour to address the British Association I ventured to emphasise this point, and I may be allowed to repeat, in a somewhat different form and for a later period, the figures then given. Taking those articles of food which are more or less produced at home, the respective proportions contributed by the United Kingdom, the rest of the Empire, and foreign countries were on the average of the five years 1910-14 as follows :

—	United Kingdom	British Empire Overseas	Foreign Countries
	Per Cent.	Per Cent.	Per Cent.
Wheat	19·0	39·3	41·7
Meat	57 9	10·7	31·4
Poultry	82·7	0·2	17·1
Eggs	67·6	0·1	32·3
Butter (including margarine)	25 1	13·3	61·6
Cheese	19·5	65·4	15·1
Milk (including cream)	95·4	0·0	4·6
Fruit	36·3	8·3	55 4
Vegetables	91·8	1·1	7·1

The war has directly affected some of our food supplies by interposing barriers against the exports of certain countries. Fortunately we were in no way dependent for any of these foods upon our enemies, though Germany was one of our main sources of supply for sugar. We received some small quantities of wheat or flour and of eggs from Germany, Hungary, and Turkey, some poultry from Austria-Hungary, and some fruit from Germany and Turkey, but the whole amount was insignificant. The practical cessation of supplies from Russia was the most serious loss, as we drew from thence on an average 9 per cent. of our wheat, 9 per cent. of our butter, and 16 per cent. of our eggs.

The rather humiliating panic which took possession during the first few days of the war of a certain section of the population, who rushed to accumulate stores of provisions, arose not only from selfishness but from insufficient appreciation of the main facts about food supplies. Our large imports of food are constantly dinned into the ears of the people, but the extent and possibilities of our native resources are practically unknown. It is very natural, therefore, that the man in the street should assume that even a temporary interruption of oversea supplies would bring us face to face with famine.

Within the first few days of the war, the Government, through the Board of Agriculture, obtained returns, not only of the stocks of all kinds of food-stuffs in the country, but also of the stocks of feeding-stuffs for animals and of fertilisers for the land. Powers were taken under the Articles of Commerce (Returns, &c.) Act to compel holders of stocks to make returns, but it is due to the trading community to say that in only two instances, so far as the Board of Agriculture was concerned, was it necessary to have recourse to compulsion. The returns of stocks of food-stuffs, feeding-stuffs, and fertilisers have been made regularly to the Board of Agriculture[8] every month since the outbreak of war, and the loyal co-operation of the traders concerned deserves cordial recognition by those whose official duty has been rendered comparatively easy by their assistance. I may be allowed to add that the readiness with which traders communicated information which was, of course, of a very confidential nature, displayed a confidence in Government Departments which they may regard with some satisfaction

A very casual glance at the national dietary suffices to show that John Bull is an omnivorous feeder, and, as the whole world has eagerly catered for his table, his demands are exigent. But, for various reasons, our daily bread, reluctant though most of us would be to be restricted to it, is regarded as the measure and index of our food supplies. On the 4th of August the Board of Agriculture published an announcement that they estimated the wheat-crop then on the verge of harvest at 7,000,000 quarters, and that, including other stocks in hand, there was at that time sufficient wheat in the country to feed the whole population for four months; and a few days later, having then obtained further information from about 160 of the principal millers, they stated that the supplies in the country were sufficient for five months' consumption. The Board also announced, on August 5, that the potato crop would furnish a full supply for a whole year's consumption without the necessity for any addition from imports. When it was further announced that the Government had taken steps to ensure against a shortage of sugar it began to be generally realised that at any rate the country was not in imminent danger of starvation. Indeed, on a broad survey of the whole situation, it was apparent that our native resources, together with the accumulated stocks of various commodities held in granaries, warehouses, and cold stores, would enable the United Kingdom to face even the unimaginable contingency of a complete blockade of all its ports for a considerable period.

Nevertheless it was abundantly evident, not only to the man in the street, but even to those whose duty it was to consider such matters, that the maintenance of regular supplies was essential to avoid undue depletion of stocks. The risk that a certain number of vessels carrying food to this country might be sunk by the enemy was obvious, and it was at first very difficult to measure it. After a year of strenuous endeavour by the enemy it is satisfactory to record that, although a few cargoes of food-stuffs have been sunk, the effect on supplies has been practically negligible.

Under these circumstances it appeared that, provided adequate protection were given against unusual risks, commercial enterprise might in the main be relied upon to supply the demands of the people in the normal manner and in the usual course of business. It is a self-evident axiom that it is better not to interfere in business matters unless there is a paramount necessity for interference.

The machinery of modern business in a highly organised community is very

[8] Returns in Scotland and Ireland are made to the Agricultural Departments of those countries and the results transmitted to the Board of Agriculture and Fisheries.

complicated; the innumerable cog-wheels are hidden while the machine is running normally, but every single one of these becomes very obvious when you attempt to introduce a crowbar. With one or two exceptions the purveyors of food to the nation were left to conduct their business without official interference, though the Board of Trade took steps to ascertain what were the retail prices justified by the wholesale conditions and to disseminate the information for the protection of consumers against unreasonable charges.

One measure of a drastic and widespread nature was adopted. The exportation of a large number of commodities was prohibited. This was done for two reasons: (1) to conserve stocks in this country, and (2) to prevent goods from reaching the enemy. The latter object could be attained only very partially by this method so long as any sources of supply other than the ports of the United Kingdom were open to the enemy or to adjoining neutral countries. The former object—with which we are now only concerned—was on the whole achieved. The Board of Agriculture, concerned for the maintenance of our flocks and herds, at once secured a general prohibition of the exportation of all kinds of feeding-stuffs for animals. Many kinds of food-stuffs were at once included and later additions were made, so that for a long time past nearly all kinds of food have been included, though in some cases the prohibition does not apply to the British Empire or to our Allies. The exportation of fertilisers, agricultural seeds, binder twine, and certain other commodities more or less directly connected with the conservation of our food supplies, was also prohibited, so that generally it may be said that the outlet for any food in the country was under effective control. This is not the time or place to discuss the reasons why in some instances limited quantities of certain articles were allowed to escape under licence. It is only necessary to remark that in all such cases there were cogent reasons in the national interest for the action taken.

Direct Government intervention in regard to food supplies was limited to three commodities—sugar, meat, and wheat. In the case of sugar the whole business of supply was taken over by the Government—a huge undertaking but administratively a comparatively simple one, owing to the fact there are no home-grown supplies. Intervention in the meat trade was necessitated by the fact that the enormous demands of the Allied armies had to be met by drafts upon one particular kind of meat and mainly from one particular source. The Board of Trade co-operated with the War Office, and a scheme was evolved whereby a very large part of the output of meat from South America and Australia comes under Government control.

As regards wheat, the intervention of the Government took two forms. The scheme whereby the importation of wheat from India was undertaken by the British Government, in co-operation with the Indian Government, arose primarily from conditions in India rather than from conditions in the United Kingdom, although it is hoped and believed that the results will prove to be mutually advantageous. Other than this the intervention of the Government in regard to wheat was devised as an insurance against the risk of interruption of normal supplies, its main object being to prevent the stocks of wheat in the country from falling to a dangerous level at a time when the home crop would be practically exhausted. When the home crop is just harvested there are ample reserves in the country for some months, and, as the United States and Canada are at the same time selling freely, stocks held by the trade are usually high. While home-grown wheat remains on the farms it is practically an additional reserve supplementary to the commercial reserves. When it leaves the farmers' hands, even although it may not actually go into consumption, it becomes part of the commercial reserve. This reserve in the nature of business tends to be constant, but fluctuates within rather wide limits under the influence of market conditions. If the price of wheat rises substantially and the capital represented by a given quantity increases, there is a natural tendency to reduce stocks. If also there is any indication of a falling market ahead, whether from favourable crop prospects or the release of supplies now held off the market for any reason, a prudent trader reduces his stocks to the smallest quantity on which he can keep his business running. So long as shipments reach this country, as in normal times they do, with, as a member of the Baltic once expressed it to me, 'the regularity of buses running down Cheapside,' the

country may safely rely on receiving its daily bread automatically. But if any interruption occurred at a time when the trade, for the reasons just indicated, happened to be running on low stocks, the margin for contingencies might be insufficient. I am, of course, debarred from discussing the method adopted or the manner in which the scheme was carried out, but, as the cereal year for which it was devised is over, it is permissible to state that the object in view was successfully achieved.

Of the 47,000,000 people who form the population of the United Kingdom the large majority are absolutely dependent for their daily food on the organisation and regular distribution of supplies. The countryman, even if he possesses no more than a pig and a garden, might exist for a short time, but the town-dweller would speedily starve if the organisation of supplies broke down. He does not, perhaps, sufficiently realise the intricacy of the commercial arrangements which make up that organisation, or the obstacles which arise when the whole economic basis of the community is disturbed by a cataclysm such as that which came upon us thirteen months ago. The sorry catchword 'Business as usual' must have sounded very ironically in the ears of many business men confronted with unforeseen and unprecedented difficulties on every side. The indomitable spirit with which they were met, the energy and determination with which they were overcome, afford further evidence of that which has been so gloriously demonstrated on land and sea, that the traditional courage and grit of the British race have not been lost.

To the question how have our oversea food supplies been maintained during the first year of the war, the best answer can be given in figures.

Imports of the principal kinds of food during the first eleven months of the war were as under, the figures for the corresponding period of 1913-14 being shown for comparison :

——	1914-15	1913-14	Increase + or Decrease — per Cent.
	Thousands of Cwts	Thousands of Cwts.	
Wheat (including flour)	113,797	115,398	— 1·39
Meat	15,868	18,026	—11·97
Bacon and hams	7,452	5,975	+24·72
Cheese	2,766	2,386	+15·93
Butter (including margarine)	5,376	5,748	— 6·47
Fruit	18,820	17,512	+ 7·53
Rice	9,573	4,840	+97·79
Sugar	35,029	38,356	— 8·67

In total weight of these food-stuffs, the quantity brought to our shores was rather larger in time of war than in time of peace. Yet one still occasionally meets a purblind pessimist who plaintively asks what the Navy is doing. This is a part of the answer. It is also a measure of the success of the much-advertised German 'blockade' for the starvation of England. So absolute a triumph of sea-power in the first year of war would have been treated as a wild dream by the most confirmed optimist two years ago. The debt which the nation owes to our sailor-men is already immeasurable. That before the enemy is crushed the debt will be increased we may be assured. The crisis of our fate has not yet passed, and we may be called upon to meet worse trials than have yet befallen us. But in the Navy is our sure and certain hope.

'That which they have done is but earnest of the things that they shall do.'

Under the protection of that silent shield the land may yield its increase untrodden by the invading foot, the trader may pursue his business undismayed by the threats of a thwarted foe, and the nation may rely that, while common prudence enjoins strict economy in husbanding our resources, sufficient supplies of food will be forthcoming for all the reasonable needs of the people.

The following Papers were then read :—

1. *Reports on Influence of War upon Supplies and Use of Fertilisers and Feeding-stuffs.*

(*a*) *The Manurial Situation and its Difficulties.* *By* Professor J. HENDRICK.

(*b*) *New Feeding-stuffs.* *By* E. T. HALNAN.

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2. *The Accumulation of Fertility in Grass-land, as a Result of Phosphatic Dressings of Basic Slag.* *By* Professor W. SOMERVILLE, *M.A., D.Sc.*

It is well known that in most cases the application of 5-10 cwt. per acre of basic slag to permanent grass-land results in a large increase in the weight of herbage, and especially of the Leguminosæ. The immediate result is that if the herbage is grazed by stock the area can carry a greater number of animals, and each individual animal makes improved increase in weight.

It appeared probable that concurrently with the stimulus to the herbage there would be an accumulation of fertility in the land, and it is a point of interest to discover the extent of such accumulated fertility. Five farms were therefore selected, where grass-land had been treated with slag during recent years, certain parts having been left undressed. About a cwt. of soil was sent to Oxford from each centre, part from grass-land that had been slagged and part from untreated land. This was put in pots in the spring of 1914, and in these pots, without further treatment, a 'crop' of oats (1914), two crops of mustard (autumn 1914), and a crop of wheat (1915) have been grown.

Five pots were filled with soil from 'slagged' and five from 'unslagged' pasture from each centre. The slag had been applied at somewhat varying times and in varying quantity at the different centres; but it is unnecessary in this abstract to go into details, except to say that the accumulation of fertility is in close relationship with the amount of slag used.

In four cases the 'slagged' soil has been found to produce increased yields of oats, mustard, and wheat, though the fertility that has accumulated has varied in degree. The 'slagged' soil from Cockle Park, which has been longest under treatment, produced—as compared with 'unslagged' soil—about 140 per cent. more oats, 30 per cent. more mustard (first crop), 70 per cent. more mustard (second crop), and about 40 per cent. more wheat, the average increase from this station being 62 per cent. Another set of soils showed an aggregate increase of 57 per cent.; other two gave increases of 12 and 8 per cent. respectively, while the fifth did not respond consistently after the oat crop, which, however, was increased by 20 per cent. Adding together all the four crops, and taking the average for the five soils, it was found that the increase was 25 per cent. It is therefore evident that the factors of production have been materially increased as a consequence of using basic slag on grass-land, a result of no small importance in view of the fact that considerable areas laid down to grass during recent years may again come under the plough.

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3. *The Composition and Uses of certain Seaweeds.* *By* Professor JAMES HENDRICK, *B.Sc., F.I.C.*

There is an old-established industry in the preparation of kelp or the ash of seaweed in certain parts of the coast crofting districts of Scotland and Ireland. This industry has experienced many ups and downs during its history and has always been a poor, badly organised, peasant industry. In recent

times the kelp has been used as a source of potash salts and of iodine, and as such has had to suffer severe competition from German potash salts and Chilian iodine. Owing to the war, there has been a revival of interest in this decaying old industry as our supplies of potash salts for manurial and other purposes have been largely cut off, and we have been endeavouring to find means of obtaining potash compounds in our own country.

It is interesting to note that in the United States also for the last few years investigations have been in progress into the possibility of using the seaweeds of the Pacific Coast as a source of potash compounds. The Americans began to investigate this subject seriously before the outbreak of the great war, but the events of the past year seem to have intensified their wise desire to make themselves independent of foreign supplies of potash. It was in connection with a movement to revive the kelp industry in Scotland that my recent investigations were made.

There are two great families of seaweeds found round our coasts, the supplies of which are plentiful enough for industrial purposes. These are (1) certain common varieties of *Fucus*, which grow between tide marks, and (2) certain varieties of *Laminaria*, and in particular *Laminaria digitata*, which grow below low-water mark but in comparatively shallow water. Analyses of these were made during the past winter and spring. It was found that *Laminaria* is richer in potash and far richer in iodine than *Fucus*. Samples of *Laminaria digitata* may contain over 2 per cent. of potash in the fresh state, or about 12 per cent. in the dry matter. At the same time they may contain 0·1 per cent. of iodine in the fresh state, or about 0·5 per cent. in the dry matter. Analyses showing the composition of different samples and especially their content of potash and iodine were given.

Observations were also made on the use of seaweeds as food for stock and for human beings, in the western islands of Scotland. Analyses were given of the varieties which were found to be used as food.

THURSDAY, SEPTEMBER 9.

Discussion on Influence of the War upon the Future of British Agriculture.

The following Papers were read :—

1. *Systems of Farming and Food-supply: the Need for more Tillage.* *By* T. H. MIDDLETON, *C.B.*

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2. *The Probable Effect of the War on the Future of Agriculture in Scotland.* *By* J. M. CAIE, *M.A., B.Sc , B.L.*

What the ultimate economic effect of the war may be is a problem of extreme complexity, and, as the condition of agriculture is closely dependent on the general economic position, any forecast of the future is necessarily both difficult and liable to error. All that is possible is

I. To state what have been the tendencies exhibited by comparatively recent changes in agriculture in Scotland;
II. To point out the salient features of Scottish agriculture at present;
III. To attempt an estimate of the future economic forces affecting agriculture;
IV. To consider in what way Scottish farmers can take advantage of these forces.

I. The chief relevant tendencies revealed by the Scottish Agricultural Statistics of the past thirty years are (1) a relatively large decrease in the area of cultivated land, and particularly of arable land, which has not been accompanied by a corresponding decrease in the numbers of live stock; and (2) some improvement in the standard of production.

II. For our purpose, the present position may be summed up in the following

table showing the distribution of the total area of land in Scotland and the numbers of live stock :

Arable land	17·28%
Permanent grass	7·82%
Rough grazings	47·97%
Woods and plantations	4·47%
Remaining area	22·46%
Cattle	1,215,000
Sheep	7,026,000
Pigs	153,000

III. A. Economic causes tending to decrease demand and lower prices of agricultural produce :

(1) Depletion of the population of the countries at war.
(2) Destruction of capital, probably causing some industrial depression.
(3) Temporary disturbance of labour market and increase of unemployment, owing to return of soldiers to civilian life.
(4) Taxation will be high.
(5) Habits of thrift may be engendered.

B. Causes operative in diminishing supplies, or otherwise raising prices :

(1) Neglect or devastation of agricultural land, resulting in lasting deterioration.
(2) Depletion of stock.
(3) Destruction of buildings, horses, implements, and all forms of farm capital.
(4) Freights may continue to be high.
(5) Owing to a certain loss of men who were skilled agriculturists, the occupation or working of land may fall to less experienced persons.
(6) With a reduction in the number of farm workers, following on heavy emigration, the rise in wages will probably be maintained.
(7) The growing demand for meat by the United States may decrease imports to this country.
(8) European countries will probably compete with us for supplies of chilled and frozen meat.

Balancing these two sets of factors, it appears likely that prices, both of bread and of meat, will be relatively high, and though costs may also be high, increased production will be economically advantageous to the farmer.

IV. Speaking generally, such increase may be either of A. bread or B. meat.

A. Some increase of the wheat area may take place, but in Scotland this area is limited, owing to conditions of soil and climate

B. There is room for expansion in the numbers, and improvement in the quality, of stock ; this improvement will take place along the lines, scientific and administrative, now being pursued. Increase in the numbers will be affected by the following factors :

(1) Improvement of grazing land.
(2) Restriction of the area exclusively devoted to sport, always with due regard to ratepayers' interests.
(3) Increased growth of turnips, oats, and other foodstuffs for winter-feeding; this will involve an extension of the arable area or a shortening of rotations, and an increased use of labour-saving appliances.
(4) Some increase in the growth of forage crops.
(5) A more general knowledge of the proper use of food-stuffs.
(6) An increase in the numbers of home-bred store stock.
(7) An increase in the numbers of pigs and poultry.

These developments will lead to greater advantage being taken of existing or new agencies of agricultural education, to an extension of co-operation, especially among small-holders, and possibly to a demand for cheaper means of railway or other transport facilities.

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3. *Scientific Aid to the Stock-feeder.* *By* Professor T. B. Wood,

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4. *Labour and Labour-saving Machinery on the Farm.*

By W. J. MALDEN.

As the need for labour-saving machinery on the farm is considerably influenced by the supply of capable men to carry out the manual work, these two cannot be dealt with separately. Hitherto in British farming, machinery has been sparingly used, so that those who would otherwise not find employment might find a living on it. There is at the present time the first real shortage, men and horses are now in really deficient number, and after the war, with the great re-shuffling of affairs, the temptations to return to it will be opposed by great temptations elsewhere. The workmen on the land in future will require all the technical knowledge of acts of husbandry that their forefathers possessed, and will have to be intelligent in other matters. The better-class farm workman is a skilled artisan; but this he rarely becomes unless early trained to it. Moreover, if not early trained, he will not stay on the land. Yet the land in the future will hold out great attractions to the worker on it. The present form of Rural Education at Board Schools drives boys from the country. Education authorities have studied general systems of education, and have not studied the boy. Rural Education to fit the boy for the land, and attract him to it, will fail until it is recognised that the physiological changes from childhood to youth have profound influence; and that muscular work, which comes naturally in childhood, is met with considerable resentment at the approach of the first change of life. The young have to be regarded in the following stages :

(1) Childhood, when the boy is in the monkey or imitative stage; willing to undergo physical exertion; not minding the monotony of continued muscular effort; under full parental influence; quick to appreciate the natural life around him; carrying no responsibilities.

(2) Youth. Becoming independent, but at present irresponsible and yet under parental protection. Spasmodic in effort mentally and physically; but with dawning ideas of future; objecting to monotony, and, if not earlier trained to physical work, strongly resisting continuous muscular effort. The muscle-untrained boy going on to the land at 14 resents hard labour, and does this so thoroughly that from the first he decides not to stay at farm work; with this decision in his mind he makes no effort to become skilled, and takes the earliest opportunity to go to towns.

(3) Approaching Manhood. Dawning ideas of duties to the State and the responsibilities of parentage. Rarely goes by choice to a physical life. But as the boy was driven from the land through his natural interests in rural life having been destroyed, and his early muscular training having been neglected, he does not come up for discussion here.

The half-timer (the half-time period being considerably prolonged) is, with further education in matters of interest and utility, the most useful man on the land, and, apart from incapables, the only one to remain on it. Fortunately, through the introduction of much new machinery in the past twenty years, and the fact that farmers feeling some shortage of men after the South African War have well equipped their farms, finds them fairly well supplied, in spite of the sudden change of position that this war has occasioned.

The delay in bringing the oil-tractor forward more quickly is, however, a more serious matter, especially as steam cultivation has declined in view of the possibilities of the oil-engine. The engines themselves have efficiency, but as yet the implement-maker and the motor-maker have not joined hands; and there is great need of this. Confused ideas which the effort to adapt attachments suitable for horse power, but utterly unsuited for mechanical power, have established, must be cleared away. Great developments will occur, including that of cutting and threshing corn in one operation; which is as practicable in England as in other countries where it has been adopted; though there will have to be special adaptations to permit it.

5. *Economics of Continuous Cropping.*
By T. WIBBERLEY, *N.D.A., N.D.D.*

Introductory.—Brief survey of the agricultural economic position of Great Britain and Ireland, special reference to latter country.

Reasons for decline of tillage area in Ireland—climate, labour, markets.

Influence of these three factors as regards tillage decline.

Continuous Cropping.—A system of intensive arable farming, specially designed to suit the climatic, labour, and market conditions obtaining in Ireland.

Comparisons between growing ordinary farm crops and roots, corn and substitutes for these crops, in connection with continuous cropping. The relative costs of productions to be discussed.

Cost of production of certain continuous crops with reference to their manurial value.

Conservation of soil nitrogen in the winter months through continuous cropping.

Effects of continuous cropping on the soil texture in winter and summer.

Evaporation of excessive soil moisture in winter through growth of continuous crops.

Possibilities of motor tillage in connection with continuous cropping and ordinary cropping compared.

Relative stock-carrying capacity of land under continuous cropping as compared with the grass farm.

Milk and beef productions from continuous crops compared with same from ordinary crops and artificial feeding.

Discussion of balance sheet of a continuous cropping farm

FRIDAY, SEPTEMBER 10.

The following Papers were read :—

1. *Methods of Estimating the Cost of Food in the Production of Milk.*
By J. MACKINTOSH, *N.O.A.*

Investigations into the cost of food in the production of milk have been carried out in several counties during recent years, but the methods of collecting the information from the farms and of calculating the cost of food per gallon have varied considerably. These differences make it impossible to compare the results obtained in the various districts; hence it is desirable that as far as possible a generally suitable and accurate method should be devised and adopted. As a basis for discussion, the methods adopted at University College, Reading, will be described.

Method of obtaining Information on:

(*a*) *Food used Indoors.*—The farmers concerned were supplied with Food Record sheets on which the kinds and quantities of the foods used each week were entered. The foods were occasionally measured or weighed when the Recorder visited the farms. This system is preferred to that of calculation from an average ration, or the ration in use at the time of the Recorder's visit. Still greater accuracy might be obtained if, as regards the bulky foods, definite clamps of roots and ricks of hay or straw could be allocated for the cows' use alone.

(*b*) *Food used Outdoors.*—The acreage of pasture and aftermath grazed by the cows was entered on the Food Record sheet; also the acreage of any soiling crops and cabbage fed to the cows either in the field or indoors.

(*c*) *Prices of Foods.*—The farmer supplied particulars as to the cost price of all purchased foods, and an allowance was added for cartage. All home-grown foods were charged at the estimated cost of production on each farm. It was difficult to get reasonably accurate estimates for crops producing only one food, *e.g.*, mangels, and much more difficult with crops producing two foods, *e.g.*, oats, but the principle of charging foods at cost price in place of market or

consuming price was adhered to as closely as possible. Some writers consider that market prices should always be charged, and this point requires thorough discussion.

The cost prices for each farm were made the basis of calculation, instead of selecting average costs and applying these to all farms. Greater accuracy for each farm is thus obtained, but comparison between farm and farm in the same district is more difficult.

(*d*) *Quantity of Milk produced.*—The total quantity of milk produced on each farm was calculated from the weekly milk records. The Recorder weighed the milk once a month, checked the weighings of the intervening weeks, and made all the necessary calculations himself.

Allowance for Manurial Values of Foods.—Careful calculations on this point have been made for the second year's work at Reading. The allowance on account of manurial residues varies considerably, according to the kind and quantity of concentrated foods and the methods of management and storage of the manure.

Allowance for Dry Cows.—Only the food fed to the cows in milk has been considered, as in the case of dry cows it has been estimated that the value of the calf or the increased value of the fat cow will balance the cost of food during the dry period.

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2. *Cost of Food in Production of Milk on Three Yorkshire Farms.* By Professor C. CROWTHER, *M.A.*, *Ph.D.*, *and* A. G. RUSTON, *B.A.*, *B.Sc.*

During the last four years investigations as to the cost of food in the production of milk have been carried out on a number of farms in the North and West Ridings of Yorkshire. In making the estimates the purchased feeding-stuffs have been taken at cost price, but for the home-grown feeding-stuffs the following arbitrary scale has been used:

Hay	55*s.* per ton	Mangels	10*s.* 6*d.* per ton
Oat Straw	30*s.* ,,	Swedes	10*s.* ,,
Barley Straw	25*s.* ,,	Turnips	8*s.* ,,

Grazing: 3*s.* 6*d.* per week for spring calvers.

During the past year detailed records have been kept on three of the farms, which enable the actual costs of production of the home-grown feeding-stuffs on these farms to be arrived at.

The main features of the results are summarised in the following tables:—

TABLE I.—*Weights of Food Consumed per Head during Last Year.*

Herd	Grass	Hay	Straw	Roots	Grain, Cakes and Meals
		cwts. st.	cwts. st.	tons cwts. st.	cwts. st.
A	27 weeks	12 4	13 4	5 12 2	14 6
B	27 ,,	1 2	24 3	5 5 6	16 2
C	26 ,,	21 5	10 2	2 7 6	16 1

TABLE II.—*Estimated Cost of Foods per Head per Year on 'Arbitrary Scale.'*

Herd	Grass and Green Fodder	Hay	Straw	Roots	Cakes, &c.	Total
	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
A	4 14 6	1 11 6	0 16 11	2 17 5	4 0 2	14 0 6
B	4 14 6	0 2 4	1 15 0	2 11 11	4 13 8	13 17 5
C	4 19 6	2 19 6	0 15 5	1 2 10	4 16 3	14 13 6

TABLE III.—*Costs of Production of Home-grown Foods.*

Herd	Grass	Hay	Straw	Roots
	Cost per Cow per Week	Cost per Ton	Cost per Ton	Cost per Ton
	s. d.	£ *s. d.*	*s. d.*	*s. d.*
A	2 0	1 13 0	10 6	5 8
B	1 7	1 8 9	15 2	7 7
C	1 9	1 11 0	14 6	8 5

TABLE IV.—*Cost of Foods per Head per Year, valuing Home-grown Foods at Cost of Production.*

Herd	Grass and Green Fodder	Hay	Straw	Roots	Cakes, &c.	Total
	£ *s. d.*	*s. d.*	*s. d.*	£ *s. d.*	£ *s. d.*	£ *s. d.*
A	2 14 0	18 11	7 1	1 11 4	4 0 2	9 11 6
B	2 2 9	1 3	18 6	1 17 7	4 13 8	9 13 9
C	2 14 0	33 7	7 4	0 19 2	4 16 3	10 10 4

TABLE V.—*Estimated Average Cost of Food per Gallon of Milk.*

Herd	Average Milk-Yield per Head per Year	'Arbitrary Scale'		'Cost Scale'	
		Total Cost of Food per Head per Year	Average Cost of Food per Gallon of Milk	Total Cost of Food per Head per Year	Average Cost of Food per Gallon of Milk
	Gallons	£ *s. d.*	Pence	£ *s. d.*	Pence
A	677	14 0 6	4·97	9 11 6	3·39
B	656	13 17 5	5·08	9 13 9	3·54
C	672	14 13 6	5·24	10 10 4	3·76

3. *Types of Upland Grazings, their Economic Value and Improvement.* *By* DONALD MACPHERSON, *B.Sc.*, *and* WILLIAM G. SMITH, *B.Sc.*, *Ph.D.*

The extent of upland grazings in Scotland comprises 48 per cent. of the total land area of the country; it is mainly devoted to sheep-farming with the Blackface and Cheviot Mountain breeds. Cattle-grazing is confined to the lower marginal areas.

The following types have been recognised, and include almost the whole of the natural pastures :—

(1) *Peatlands.*—The peat cap of the upland plateau areas. Heather (*Calluna*); cottongrass (*Eriophorum*); and deer-hair grass (*Scirpus cæspitosus*) are dominant plants and provide valuable spring grazing. Retrogression of peat is widespread.

(2) *Nardus Grassland.*—*Nardus stricta* grassland occurs on wasting peat on steep slopes marginal to the moorland. It invades and is successive to the vegetation of the peatlands. It is of secondary grazing value.

(3) *Heatherlands.*—On slopes where continuous leaching has impoverished the upper layers of the lighter soils, and where slow accumulation of humus occurs. These form valuable grazing ground at all seasons.

(4) *Molinia Grassland.*—*Molinia cærulea* grassland, on gentle wet slopes with peat. When pure it is of secondary grazing value.

(5) *Alluvial and Flush Grasslands.*—These provide the best pasturage on streamside alluvials and on hill slopes flushed with water from springs. They may be utilised as wintering grounds or enclosed as meadows. The alluvia of the upper valleys are light, and accordingly retrogression occurs through leaching where flushing is prevented. The lower valley alluvia tend to be heavier and their maintenance as grazing units depends on drainage.

This habitat offers conditions suitable to invasion by bracken.

The extent and distribution of the individual types are determined chiefly by topography and climate, but past history and interference by animals or man are important, *e.g.*, grazing, burning, draining, liming.

The types are relatively constant throughout, but may occur in various combinations in association with differences in the factors. Thus in different localities the grazing areas present distinctive features. This involves different systems of management, *e.g.*, dry south-eastern area and humid western area of Scotland. Alluvial and flush grasslands, heatherlands, and peatlands are most valuable to the grazier. *Nardus* and *Molinia* are of secondary importance.

The value of a grazing depends on a suitable representation of types and on their relative disposition. 'Hirsel' charts indicate the best combination of types.

Improvement.

Alluvial and Flush Grasslands.—These can be made to replace heather and *Nardus* by suitable irrigation with water derived from springs or with surface water bearing rainwash. Invasion of acid water deteriorates the pasture, favours *Nardus*, and, where 'pan' is formed, promotes retrogression to moorland. These grasslands are suitable subjects for manurial treatment, *e.g.*, basic slag. Destruction of bracken increases the productive capacity of the pasture.

Heatherlands.—The grazing value is greatly increased by regular burning on a suitable rotation. Renewal of burnt areas results through: (1) Growth from the shoot; (2) Colonisation by seedlings. The former gives the most rapid recovery. Types of heatherland with slow and rapid rejuvenating powers require different burning rotations respectively.

Peatlands.—Draining increases the proportion of heather but reduces that of cottongrass and deer-hair grass, and favours invasion of *Nardus*. Little improvement is possible.

Nardus.—Where flushing is possible good pasture may be induced, otherwise in *Nardus* and *Molinia* areas grazing value is improved by burning on a short rotation.

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4. *On the Effect of Increasing the Amount of Calcium Phosphate in the Rations of Cows on the Composition of the Milk.* By A. Lauder, *D.Sc., F.I.C., and* T. W. Fagan, *M.A.*

The investigations of previous workers on this subject were reviewed;[1] while there was not complete agreement between their conclusions, the general opinion was that the composition of the mineral matter in the milk could not be readily affected by adding mineral matter to the food.

For the present investigation six cows of the dairy Shorthorn breed were selected, as nearly equal as possible in regard to age and period of lactation. They were then divided into two lots of three each. The yield of milk given by each cow was determined at every milking by weighing. Weekly samples of the milk of each cow were also taken for analysis, and the percentages of phosphoric acid, ash, fat, and 'solids not fat' determined.

[1] Duclaux, *Ann. Inst. Pasteur*, 1893, 2–17, *Chem. Soc. Journal*, **64** (1893), ii. 582; Neumann, *Milch Zeit.* **22**, 701–704, *Chem. Soc. Journal*, **66** (1894), ii. 246; Weiske, *Landw. Versuchs-Stat.*, 1894, **45**, 242–245, *Chem. Soc. Journal*, **66** (1894), ii. 246; Neumann, *J. Landw.* 1894, **42**, 33; Von Wendt, *Chem. Zeit.* 1908, ii. 1881, *Chem. Soc. Journal*, **96** (1909), ii. 164; Fingerling, *Landw. Versuchs-Stat.*, 1911, **75**, 1, *Chem. Soc. Journal*, **100** (1911), ii. 510.

The cows received the following ration :—

75 lb. turnips.
4 ,, Bombay cotton cake.
1 ,, bran.
8 ,, hay.
straw (ad lib.).

The mineral matter in this ration, exclusive of the straw, contained about ·5 lb. of calcium phosphate.

The analyses made during the preliminary period showed that the percentage of phosphoric acid and mineral matter in the milk of each cow was relatively constant, although there were slight differences in the amount when one cow was compared with another. The percentage of fat, as is usually the case, showed more variation.

Lot I. was kept on the same ration during the whole period of the experiment. To the other lot calcium phosphate was fed in gradually increasing quantity—two, four, six, and finally eight ounces per head per day, the latter amount being fed for three weeks. The addition of calcium phosphate was then stopped and the original ration continued for other two weeks.

An examination of the percentages of phosphoric acid found shows that the addition of calcium phosphate has not increased the amount of phosphoric acid in the milk. There is practically no change, and the results vary less than those obtained from Lot I., where the cows were on the same ration all the time. Since the cows were receiving calcium phosphate over a period of five weeks, Neumann's criticism that the negative result is due to the experiment not being continued sufficiently long is inapplicable in this case. The increase in the amount of phosphoric acid (·0172) which he claims to have effected appears to be well within the ordinary limits of variation.

In the same way, an examination of the percentages of fat, ash, and 'solids not fat' obtained does not indicate that the extra calcium phosphate fed to Lot II. has had any effect on the amount of these substances secreted. Finally, no definite effect on the yield can be observed.

Percentage of Phosphoric Acid in the Milk.

Lot I. (No Phosphate.)

Date	Cow 1		Cow 2		Cow 3	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
December 10	0·26	0·24	0·25	0·23	0·24	0·24
,, 17	0·28	0·24	0·24	0·23	0·21	0·24
January 7	0·25	0·26	0·23	0·23	0·21	0·25
,, 14	0·27	0·27	0·24	0·24	0·23	0·22
Average	0·26	0·25	0·24	0·23	0·22	0·24
January 21	0·27	0·27	0 24	0·24	0·25	0·27
,, 28	0·29	0·29	0·26	0·26	0·27	0·27
February 4	0·28	0·28	0·23	0·29	0·26	0·26
,, 11	0·30	0·29	0·26	0·21	0·28	0·20
,, 18	0·29	0·29	0·25	0·24	0·26	0·26
Average	0·28	0·28	0·25	0·25	0·26	0·25
February 25	0·29	0·29	0·24	0·25	0·25	0·25
March 4	0·29	0·29	0·23	0·24	0·27	0·26
Average	0·29	0·29	0·23	0·24	0·26	0·25

Lot II. (With Phosphate.)

Date	Cow 4		Cow 5		Cow 6	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
December 10	0·22	0·19	0·33	0·28	0·25	—
„ 17	0·20	0·20	0·28	0·27	0·23	0·21
January 7	0·19	0·19	0·25	0·26	0·22	0·22
„ 14	0·22	0·21	0·26	0·29	0·22	0·26
Average	0·21	0·19	0·28	0·27	0·23	0·23
January 21	0·22	0·22	0·28	0·27	0·22	0·22
„ 28	0·22	0·23	0·29	0·26	0·22	0·22
February 4	0·20	0·22	0·26	0·26	0·24	0·24
„ 11	0·21	0·19	0·29	0·30	0·24	0·23
„ 18	0·21	0·21	0·28	0·29	0·22	0·22
Average	0·21	0·21	0·28	0·27	0·23	0·23
February 25	0·22	0·21	0·28	0·28	0·23	0·22
March 4	0·20	0·23	0·27	0·29	0·23	0·22
Average	0·21	0·22	0·27	0·28	0·23	0·22

5. *The Significance of the Act of Milking.*
By Professor C. Crowther, *M.A., Ph.D.*

The operation of milking serves to remove pre-formed milk from the udder, but it is possible that, in addition, the handling of the teats may impart a stimulus to further vigorous secretion during the period of milking. Data were adduced in support of the latter hypothesis.

Further tests, in which the 'quarters' were milked separately, and the milk from each 'quarter' collected in fractions, show that whereas in the case of the first 'quarter' milked there is a tendency for the percentage of fat in the milk to rise steadily from the earliest-drawn to the last-drawn fractions, this tendency is much less pronounced in the case of the other 'quarters,' and indeed, in the case of the 'quarter' milked last, the tendency for a considerable portion of the milking is for the percentage of fat to fall rather than to rise. In all cases there is a very rapid rise in the percentage of fat towards the close of milking. If the 'quarters' be milked in pairs, the records of the first pair resemble those of a 'first quarter' and those of the last pair resemble the records of a 'last quarter.' If the four 'quarters' be milked simultaneously the records of each resemble those of a 'first quarter.' These conclusions are not affected by the order in which the 'quarters' are milked.

Taking the produce of each 'quarter' as a whole, it was found almost invariably that the milk from the 'quarter' milked first was the richest in fat, and that from the last 'quarter' was poorest in fat. In thirty-seven comparisons of first and last 'quarters' milked singly the former gave the richer milk on thirty-four occasions, the average percentages of fat being 4·26 (±·15) and 3·10 (±·13) respectively. In ninety-five comparisons in which the 'quarters' were milked in pairs, the first pair milked gave the richer milk on sixty-five occasions.

The foregoing observations led to the conclusion that the time-factor must be of considerable importance in milking. This was confirmed by a comparison of very quick and very slow milking by ordinary methods, which showed a difference of 10 per cent. of milk-yield and 40 per cent. of fat-yield in favour of the quick milking.

A further comparison was made of ordinary milking, taking the teats in pairs, and simultaneous milking, by two milkers, of all four quarters. A difference of 2 per cent. in milk-yield and 6 per cent. in fat-yield in favour of the latter method was indicated, despite the occasional disturbance of the cow inevitable with this mode of milking. Further tests with the milking-machine are proposed.

6. *The Plant as an Index of Smoke-pollution.* *By* Professor C. CROWTHER, *M.A.*, *Ph.D.*, *and* A. G. RUSTON, *B.A.*, *B.Sc.*

Results obtained in several years' experiments and observations in and around Leeds are summarised under the following heads :—

1. The general type of vegetation in smoke-infested areas.
2. The general appearance of individual smoke-damaged plants.
3. The specific effects of smoke-damage in plants.

1. Trees and shrubs make only a stunted growth; dead and dying trees are common objects. Conifers are particularly sensitive. Plants with thick, tough leaf-cuticle (*e.g.*, iris, auricula) are more resistant than those with thin cuticle and crinkled, hairy surface (*e.g.*, primrose) Most bulbous and seed-bearing plants are sensitive to smoke. In areas badly infested with smoke, coarse grasses (bent, couch, Yorkshire fog) and weeds (dock, sorrel, plantain) monopolise the meadows and lawns, leguminous plants rapidly disappear, whilst the hawthorn hedge barely persists. Rhubarb does not seem to be affected, and the elder can be successfully grown.

2. Destruction of young shoots and buds is noticeable. Characteristic discolouration of leaves takes place apart from the inevitable coating of tarry soot, and the fall of the leaf is greatly accelerated. The colours of flowers fall short of their normal intensity, blues and reds tending to run to white, and bronzes to pale yellow.

3. Previous observations as to the choking of stomata by soot particles have been confirmed. Tintometric measurements show a certain degree of correlation between depth of tint of flowers and atmospheric-pollution.

The correlation between plant-growth and atmospheric-pollution previously established by measurements of rate of assimilation has been confirmed by actual vegetation tests in the garden and in the field. In the garden tests within the city boundaries the produce (three crops) obtained in the 'cleanest' garden was fully three times greater than that obtained in the 'dirtiest' area. In the field tests made outside the city the difference between extremes (one season's crops) was fully 20 per cent. In soils long exposed to smoke-pollution there is a marked failure of root-development, root-hairs and fibrous roots being few or absent.

The chemical composition of plants grown in polluted areas shows a relatively high content of sulphur, chlorine, and arsenic—an abnormally high proportion of the sulphur being in non-protein forms.

In the case of seed-bearing plants smoke-pollution has been found to cause a decrease in size and weight of seed, and a lowering of germination-capacity and germination-energy.

Inhibitory effects upon enzyme-activity have been demonstrated by comparative measurements of oxidase-, catalase-, lipase-, and emulsin-activity.

Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. WILFRED MARK WEBB (*Secretary*), Rev. J. O. BEVAN, Sir EDWARD BRABROOK, Sir H. G. FORDHAM, Dr. J. G. GARSON, Principal E. H. GRIFFITHS, Dr. A. C. HADDON, Mr. T. V. HOLMES, Mr. J. HOPKINSON, Mr. A. L. LEWIS, Rev. T. R. R. STEBBING, *and the* PRESIDENT *and* GENERAL OFFICERS. (*Drawn up by the Secretary.*)

THE Committee recommends that the Warrington Society should be made an Associated Society.

Sir T. H. Holland, K.C.I.E., D.Sc., F.R.S., has kindly undertaken to act as Chairman at the Conference of Delegates to be held at Manchester, and has chosen 'The Organisation of Scientific Societies' as the subject of his Address.

Mr. William Whitaker, B.A., F.R.S., has been so good as to accept the Vice-Chairmanship.

The Committee has chosen the following subjects for discussion at the Conference:—

'Local Museums' (suggested by the Selborne Society), to be introduced by Dr. W. E. Hoyle, M A., and 'Colour Standards' (proposed by the British Mycological Society), to be introduced by Mr. J. Ramsbottom, M.A.

The Committee asks to be reappointed, and applies for a grant of 25*l*.

Report of the Conference of Delegates of Corresponding Societies held at Manchester on Wednesday, September 8, *and Friday, September* 10, 1915.

Chairman . .	Sir Thomas Holland, K.C.I.E., D.Sc., F.R.S.
Vice-Chairman .	William Whitaker, B.A., F.R.S.
Secretary . .	Wilfred Mark Webb, F.L.S.

ON taking the chair, Sir Thomas Holland called upon the Secretary to make an announcement which was to the effect that the General Committee, on the recommendation of the Council, had sanctioned an alteration in the Rules of the British Association, subject to the report of the Committee of Recommendations, so that the Chairman and Vice-Chairman of the Conference of Delegates would in future have the title of President and Vice-President respectively. This information having been received with applause, Sir Thomas Holland proceeded to deliver his Address on

The Organisation of Scientific Societies.

Among the many lessons we learn in every great war there is always one that stands out prominently as something of fundamental and national importance. In the Crimea our shortcomings in commissariat organisation were demonstrated with painful emphasis In South Africa we learnt something of the way in which the initiative of the individual, naturally more prominent in the amateur soldier, triumphs, under unforeseen circumstances, over any system fixed by formal and traditional discipline. The great war now in progress will result more completely than any of its puny predecessors in recasting our national ideals—economic, political, and military.

Of all the lessons we are likely to learn, the one that so far promises most to affect the life of the nation may be summed up in the word *organisation*. The fuss made lately about the shortage of munitions; the discovery in the ranks of the Army, and among its officers, of thousands who are only amateur fighters, but are professionally trained technologists; the recasting of the Cabinet; the introduction, twelve months after the commencement of the war, of legislation to register and classify the technical qualifications of the people; the repeated occurrence of coal strikes on a large scale, settled only by the intervention of Cabinet Ministers, and by an obviously temporary compromise, are all confessions of our shortcomings in national organisation—shortcomings that have cost the country thousands of lives.

On the other side of the 'front' we see organisation raised to the level of a national cult—*Kultur*—with the result that, while efficiency in action and economy in the utilisation of a country's resources have been raised to a standard hitherto unknown, and by us undreamt of, the human instincts have been drilled out of existence, and Germany stands alone as an almost perfect machine in action, but, like a machine, unable to understand the rest of the human race—admired for its mechanical efficiency, but loathed for its degradation of the great human instincts of liberty and toleration.

But between these extremes there must be a course of maximum wisdom; for admittedly both the organisation of the community (the feature which is supposed to dominate the professional classes) and freedom of the individual (the prerogative of the amateur) are necessary for the progress of what is best in civilisation.

Every meeting of the British Association reminds us that early in the last century a body of learned men realised that the form of study popularly known as scientific needed organising, required the strengthening influence of a protective guild—the formation of a cult—in order that its value might be forced on the popular mind. Long before the foundation of the British Association, a comparatively small number of men had interested themselves in scientific problems, and their work had so far progressed as to require specialisation, with the foundation of distinct societies. This specialisation found expression at the first three meetings of the Association by the formation of committees for (1) Mathematics and General Physics, (2) Chemistry and Mineralogy, (3) Geology and Geography, (4) Zoology and Botany, (5) Anatomy and Physiology, and (6) Statistics.

These six groups have developed into our present twelve Sections, with extra Sub-Sections; and in practice every Section, by classification of its papers and in the conduct of its discussions, acknowledges a further specialisation that is none the less real because it has not yet been formally recognised in organisation.

It is difficult for us to realise that, although the collection of scientific data and thought had made such progress eighty-four years ago as to require the sub-division indicated by the first institution of the British Association, the importance of science was still hardly recognised among the so-called learned and the ruling classes. Obvious, if insufficient, progress had been made since the days when it was possible for Dean Swift to issue, as tolerable literature, his satires on the Royal Society, or for Robert South to add to his doubtful popularity by describing its members as incapable of admiring anything except 'fleas, lice, and themselves.'

Although science now takes its place on equal terms with literature in the world of academic culture, we have so far succeeded only to a very small extent in getting the professors of pure science to co-operate in unison with the captains of industry who depend entirely, consciously or otherwise, on the application of scientific laws to industrial problems.

There has hitherto been a tendency for scientific and literary men to gather together under one banner, with the motto 'learned,' but a more natural association should be indicated by the community of interests between scientific men and technical experts. The student of pure science often discovers laws or formulates theories which are but accidentally carried beyond the purely intellectual world. On the other hand, technical experts frequently work by empirical methods that are discovered either by accident or as the result of many costly blunders. The growth of science and of commercial technology has been largely independent and unrelated, that is, without organisation.

The absence of this organisation has shown itself for many years to those who are able to read the signs of the times by the way in which German applied science has assisted commercial activity in trespassing on markets created and formerly occupied by British enterprise. The result of organised co-operation on the one hand, and of disconnected effort on the other, has now been brought home to us all, suddenly and painfully, by the war. In the utilisation of technical science the German army has had an enormous advantage, for which we have had to pay by the lives of some of our best officers and men.

In Germany the scientific, technical, and commercial community (not communities) is mobilised, and each individual in it has been given his appropriate function. In this country, on the other hand, we still have endless instances of right men in wrong places, while scientific activity seems to be devoted to the voluntary formation of innumerable and often irresponsible committees, with overlapping functions, and with no apparent common aim in view. Nothing could more clearly demonstrate our shortcomings in organisation than the columns of the daily Press, which are filled with complaints from scientific men, who, though among the most distinguished in the world of pure science, are in this great struggle still unemployed, and unfortunately often show by the tone of their complaints that they are also unemployable.

A small fraction of the time now devoted in this country to discussions in committee would be sufficient, if turned to well-directed effort, to remove many of the handicaps from which our Navy and Army are now suffering in this critical stage of the war. Most of our committees might be justifiably likened to two athletes at the east end of a church discussing the better route by which to get round to the tower, while a cripple starts off at once by one of the routes (possibly even by the less easy of the two); yet the cripple gets there while the athletes are still wrangling.

The root trouble with us is due to the fact that our committees are generally composed of members appointed, not because they are best able to solve the problem in hand, but because they represent vested interests; and vested interests have now grown to dimensions beyond power of removal, because our institutions are often the products of worthy, local, unconnected, and therefore unorganised effort.

In their relations to one another institutions that profess a common public aim show a spirit of jealous competition more prominently than any community of ideal. One cannot study the recent history of University education in London without being painfully impressed with the fact that internal friction in a machine without design results in a consumption of energy that costs more than the educational output is worth.

Our scientific and technical societies similarly suffer from overlapping and conflicting interests, and this Conference will be of some value if, instead of discussing for once some special scientific problem, its members become inspired with a desire to direct the activities of the societies they represent, so as to reduce the quantity of machinery; to correlate their activities with those of the metropolitan institutions with headquarters in London; to subdivide those institutions composed of dissimilar elements, and to assist, so far as practicable, the regrouping of those who work with common data and with a common aim.

An excellent illustration exists of the way in which reform of this kind is possible when members are sufficiently public-spirited to distinguish between the wider interests of science and those of their own special societies. Up to 1889 there were in this country about eight separate societies devoted to the technical interests of coal mining. In that year four of these societies federated their interests, and during the few following years three others joined the federation, and pooled their resources to meet the cost of a common publication and to maintain a common office at Newcastle.

In 1892 the Institution of Mining and Metallurgy was founded in London to meet the wants of technologists devoted mainly to the requirements of metalliferous mining. The rapid growth of this institution, its metropolitan location, and its comprehensive name, challenged the premier position of the Federated Institution of Mining Engineers. The latter consequently changed its name to *The* Institution of Mining Engineers, and moved its central office to London. Thenceforward each institution not only published papers on its own special branch of mining, but trespassed frequently on the natural domains

of its competitor. Later, when one of these institutions applied for a Royal Charter, the other, in its own interests, successfully opposed the application.

But in 1913, through the happy possession of two Presidents who could distinguish parochial from national interests, both institutions agreed to a delimitation of their spheres of influence, and each supported with success the petition of the other for a Royal Charter. They are now no longer competitors, but sister institutions; and, instead of competing for recruits, they can afford to define and maintain a common standard of technical qualification and professional etiquette for the British mining engineer.

One of the first principles observed by a student of science is that of classification. Classification means not merely the bringing together of things that are similar in some essential feature; it also means the separation of those that are essentially unlike, although superficially bearing some form of resemblance.

One realises how hard it is to apply the pruning knife of scientific classification when one contemplates the spectacle of the various 'literary and philosophical societies' which still survive, mostly under financial difficulties, in many of our large provincial cities, vainly endeavouring to cover 'the whole realm of Nature.' Such societies, embracing the general range of sciences, and sometimes even including literary subjects, exist at Aberdeen (founded in 1840), Birmingham (1858), Cambridge (1819), Edinburgh (1731), Glasgow (1802), Leeds (1820), Manchester (1781), and Newcastle (1793); while at Dublin, where individuality seems ever to flourish in various departments of civilised activity, there are two such societies, with apparently overlapping interests in general science: the Royal Dublin Society, founded in 1731, and the Royal Irish Academy, founded in 1785.

There are not many among these societies whose publications can be safely neglected by the research worker in any of the specialised branches of science, and yet most of them could not show an average annual output of one serious paper in each of the science subjects as defined by the twelve Sections of the British Association. They become in turn the fortunate victims of some local enthusiast, who in time passes away like a comet or finds wider scope for his ambitions, either in the Royal Society of London, or in the metropolitan society that governs his own pet subject, where his products enjoy the benefit of more thorough discussion, and sometimes appreciation, by fellow experts. He removes his attentions from the gallery to tickle the fancy of the stalls.

If we take the Literary and Philosophical Society of this city, which has for many years devoted itself almost entirely to science, and issues memoirs which no serious worker can afford to overlook, we get an example of the way in which the student is taxed in his search for the 'previous literature.' Of ninety-one papers published in *The Manchester Memoirs* during the past five years, as many as thirty-four belong to a class that would be referred to Section A of this Association, this abundant enthusiasm being largely due to a local occurrence of radio-activity. Of the remainder, ten would come under Section B, seven—entirely palæontological in character—come under Section C, twenty-two under Section D, two under Section H, two under Section I, thirteen under Section K, and one under Section M.

One can sympathise with those readers who grumble at one halfpennyworth of geological bread to this intolerable deal of physical and biological sack.

Now, it is important to remember that this Society is maintained by fewer than 150 members, many of whom are members only through general interest in science, or merely in consequence of a commendable desire to keep alive an institution which has an honourable record. Thus the critical discussion of most papers presented must be confined to a very small number, and herein arises a danger that may at any time give rise to consequences far more serious than the burial of a paper with an overburden of unrelated literature; for the author of the paper himself must often be the only member capable of deciding as to whether his paper is or is not suitable for record as a definite addition to scientific data or thought.

To the outside student, therefore, the publication of a paper by such a small society gives no *prima facie* reason for regarding it as a serious and probably trustworthy addition to scientific literature. The papers so issued must be most embarrassingly unequal, and wholly indeterminate in character; yet no stranger can run the risk of disregarding such publications.

But the tax thus laid on students of scientific literature is not the only drawback or danger due to the activities of such small, local, non-specialised societies. They often possess collections of natural-history specimens or of physical instruments for which they become, by mere possession, trustees to the whole scientific world. As in the case of published literature, the circumstance that these things are often unknown to the rest of the world, or are almost inaccessible to the student, is only one, and not the most serious, danger; for one knows instances of collections suffering from neglect, or, still worse, suffering from the activities of some member who temporarily dominates the governing body, and entertains strong views as to the cost of maintaining collections that, from his special point of view, are of no value.

Before proposing, in the name of Organisation, to abolish such unspecialised societies, or before hinting that they have outlived their times, or before even suggesting that they might now be allowed to die a natural and respectable death, one should exert one's ingenuity to devise some scheme for turning them to account. They inherit traditions in most cases that only an unregenerate iconoclast would despise; most of them were founded when science was barely specialised, and when facilities for attending London meetings were imperfect; many of them have published memoirs that are now of classical value, and they have included among their active members the most worthy names in the history of science; most of them possess libraries that could not now be purchased for money, although these are often neglected, and, for financial reasons, often difficult to use.

Even as monuments, therefore, societies such as those that I have mentioned deserve preservation. How, then, can one turn their resources to good account, and organise their culture without the drawbacks of *Kultur*?

The plan that has often occurred to me as a possible compromise between the claims of central organisation and of provincial autonomy is this. The recognised chief among such societies—the Royal Society of London—should, by affiliation of its provincial poor relations, take over the cost, as well as the responsibility, of their serious publications. They would enjoy home rule so far as their meetings, discussions, finances, and libraries are concerned; but the papers offered for publication would be censored, in the usual way, by the appropriate sectional committees of the Royal Society; and, if passed, would be published, either in the *Proceedings* or *Transactions* of the Royal or of some metropolitan specialised society. Such papers would then rank technically, not by mere courtesy, as 'publications' for purposes of quotation or priority. The local interest in science would not then be curtailed, and the geographical handicap, especially of junior provincial workers, would be removed; while the provincial scientific communities would be able to maintain their treasured monuments, without, as now, a constant fear of financial difficulties, and without a recurring dread that senility in the respected old 'lit. and phil.' will soon end in the way of all things living.

So far as our local example is concerned, many, if not most, of the papers which I have just classified by the British Association system might well have been accepted by the Royal Society; for the majority of the papers published in its *Proceedings* are also by non-members. The last six volumes of the *Proceedings of the Royal Society* contain papers by 384 authors, of whom only 141 are fellows of the Society.

I am quite aware of many difficulties in the way of this proposal: fears, on the one side, that the Council of the Royal Society will acquire a dangerous power of controlling the freedom of the scientific writer; and forebodings, on the other, that the duties of the Council threaten to become 'heavy burdens and grievous to be borne'; while the cost of such additional publications will be removed from the local body to be thrust upon the Royal Society.

With regard to these objections, the circumstance that a young worker's paper has been hall-marked by the Royal Society will soon be regarded as fair compensation for what would, after all, be but partial loss of freedom; for the local societies, as well as the various journals, can still publish what they like, though the foreign student may not be blamed for neglecting any but technically published scientific literature.

The extra burdens added to the Council and Sectional Committees of the

Royal Society are merely of a kind that someone *must* undertake, if we are to have any regard at all for the progress of science; and it will soon be necessary for the State to recognise the national value of the work done by the Council and Committees of the Royal Society in more ways than nominal recognition of their ornamental positions.

In practically every country on the Continent of Europe the premier learned academies, that occupy positions corresponding to the Royal Society of London, are financially supported by the State, and even the ordinary members are paid.

In this country scientific organisations, like the universities, are largely dependent on private charity, with the result that, while we get the benefits of individuality and local competition, we suffer, as the war has already proved to us, the necessary loss of power, due to an undesirable number of wheels in our machine, due to unnecessary duplication of effort, and due to industrial and financial eddies in the stream of progress; in a word, due to want of method and organisation. That is the theme which I wish the delegates present to take back for practical consideration by the societies that they represent.

It is important to remember that organisation necessarily requires someone to take the lead and someone to fill the subordinate's place, otherwise all is anarchy; and, whatever may be the discipline within each society, their relations to one another at present can but be described as anarchy. The fellow of the Royal Society has no more responsibility at present than any member of the smallest debating club. His selection is regarded as an honour, but an honour is as meaningless as an iron cross if it does not imply responsibility and an opportunity for more work. What applies to an individual applies to a society of such persons. The premier position of the Royal Society is acknowledged by every British worker in science, and those societies which similarly embrace all phases of science can assist the aims of organisation by reminding the Royal Society that its position is more than ornamental, and that its lead will be welcomed.

Sir EDWARD BRABROOK proposed, and Mr. WILLIAM WHITAKER seconded, a vote of thanks to the Chairman for his Address. This was carried with great cordiality, and acknowledged by the Chairman.

The subjects chosen for discussion were (1) 'Local Museums,' (2) 'Colour Standards.' The first was introduced by Dr. W. E. HOYLE.

Local Museums.

The duty of the opener of a discussion, as I understand it, is not to present an exhaustive treatise on the subject entrusted to him, but merely to throw down, as it were, certain 'bones of contention' which those present may worry to their hearts' content. I shall, therefore, with all possible brevity, place before you a few theses, and leave you to fill up the too obvious lacunæ in my observations.

May I lay it down at the outset that the first and fundamental function of a museum is to preserve? We museum officials are nowadays given so much good advice about the desirability of making our exhibits æsthetically attractive, of compiling explanatory labels which shall at the same time instruct the specialist and interest the casual visitor, and of catering for school children, that we are perhaps in danger of forgetting that our paramount duty is to see that 'neither moth nor rust doth corrupt,' and that 'thieves do not break through nor steal.' It always tends to clearness of thought in approaching any subject to begin with a definition. I will therefore provisionally define a 'local museum' as a museum existing in a place, belonging to that place, destined for the instruction and delight of the dwellers in that place, and illustrative of that place, and will leave to my critics the congenial task of picking holes in my definition.

It follows from this that the first duty of a local museum is to preserve the things of interest pertaining to the locality, whether they illustrate its history, folklore, natural history, or any other topic. These must be carefully kept, and every particular relating to them recorded with scrupulous accuracy. A certain proportion must be exhibited in such a way that their points of interest may

be readily seen, and they must be adequately labelled—all this in accordance with principles which are nowadays well understood by every qualified museum official. Complete reference collections of animals, plants, fossils, and the like must be formed and kept in cabinets accessible to those desiring to make use of them for purposes of study.

Here, I think, it is necessary to consider the important and delicate question: What ought to be the relations between the local museum and the national museum? Broadly stated, the solution is to be found in the general principle, what is of national importance should be preserved in the national museum; what is of merely local interest should be kept in the local museum. Like many general principles, this is quite easy till we begin to apply it to particular cases. These require judgment and tact for their successful negotiation. May I give one single instance? In a remote part of the Celtic Fringe is a mass of sand dunes which cover what was once a city of sufficient importance to have a Royal Charter, a roll of burgesses, and a mace. In 1886 the corporation was dissolved: the burgesses, their sons and widows, were each to receive the sum of eleven shillings per annum, and the mace was kept in a public-house, where it was produced for the inspection of anyone who cared to pay for a drink in order to have a look at it. Such an arrangement had obvious dangers, and the national museum naturally wished to have possession of the mace. It was found that the burgesses had no power to give it, but they consented to deposit it in the museum provided a replica were furnished to be kept in the public-house. This was agreed to, and a replica, which is hardly distinguishable from the original, was provided, and I am informed by a recent visitor that the landlady continues to exhibit it as the original, so that all parties are satisfied.

It having been admitted that the formation and preservation of a local collection is the prime duty of a local museum, and supposing this function to be adequately discharged, should a local museum undertake any others? I should say, 'Certainly, if its means and opportunities allow,' and the possibilities are many and various. One obvious way in which the museum can be of the greatest service is by providing collections which shall give the visitor a preliminary sketch of some department of knowledge. I allude to what are often called 'index' collections, though the term 'introductory' collections would be more appropriate.

For instance, a larger or smaller collection, illustrating the animal kingdom, would furnish a suitable preliminary to a study of the local fauna; a series of specimens showing the technique of different processes of engraving, etching, and mezzotint would furnish a valuable introduction to a collection of local prints; a number of objects from different prehistoric and historic periods would enable the visitor to place in their proper chronological relation the collections of local archæology; and numerous other possibilities will readily suggest themselves.

Another direction in which a local museum may profitably develop is by coming into direct connection with the educational system of the locality. This may be done either by setting apart and furnishing a room for the special use of school classes, or by providing topical collections, which can be lent to, or circulated among, the schools. There is already an extensive literature on this subject, so I need not enlarge further upon it, the more so as a committee of this Association is actively engaged in studying the educational uses of museums.

Furthermore, there is, to my mind, nothing out of place in a local museum developing a special subject, quite disconnected with the locality, if it has the power to do so without interfering with its proper work. Suppose, for example, that some well-to-do citizen has acquired an important collection, say, of seventeenth-century furniture or Japanese works of art, which he is desirous of giving or bequeathing to his native town. There is no objection to the museum accepting such a gift and developing it to the best of its power. It will be a source of pride and delight to the inhabitants; and, if it is not so to begin with, may become a collection of real importance, which will attract specialists to visit and study it, greatly to the advantage of the museum and the town.

As instances of such collections may be mentioned the Gurney collection of raptorial birds in the Norwich Museum, and the Egyptian collections in the Manchester Museum.

I may, however, remark, by way of parenthesis, that the generous donor leaves his work half done, if he bequeaths a collection without also providing some means for its maintenance and development; and he is by no means a benefactor if he attaches to his gift embarrassing stipulations as to its being always exhibited in cases of a particular type, and excludes the possibility of its enlargement and development.

May I conclude in the words of a great teacher, applicable to local as to other museums—'The first function of a museum is to give an example of perfect order and elegance. Everything should be in its own place, everything looking its best because it is *there*. Nothing should be crowded; nothing unnecessary. The museum is only for what is eternally right and well done.

'The least things are there and the greatest and all good.
'The simple may go there to learn and the wise to remember.'

Dr. F. A. Bather, referring to the distinction between objects of national and local interest, urged that the principle which should guide local curators in their selection should be the advancement of science. This was to be considered, first from the standpoint of the local public, whose needs were best met by objects of introductory educational value; secondly, from the standpoint of the researcher, who might live in the locality or might come from the ends of the world. To meet the needs of the latter, material should not be scattered through hundreds of museums, but should rather be grouped in convenient centres, not necessarily national. Such a researcher would naturally seek for local objects, *e.g.*, fossils, in a local museum, but he ought not to have to seek for, say, New Zealand fossils through all the museums of the British Isles. If a museum happened to have had presented to it such exotic objects, not utilised for its own educational purposes, it should exchange them with a museum (national or local) that had laid itself out to collect and preserve that special class of objects. Type-specimens, above all, should be placed in museums where they would be well looked after, and would be readily accessible to specialists. In exchange for such unique or extraneous objects the local museum might obtain series of objects more suited to the educational needs of its locality.

Dr. Marie C. Stopes urged that one of the functions of local museums is to make and preserve permanent cinematograph records of events, human or natural, of importance and interest: these records should not only be preserved for posterity, but also exhibited from time to time and explained to the young people and others; and also submitted the view that there may be a balance of good in the decentralised state of collections, even of type-specimens. The visiting of local museums brings a stimulus to the local and often isolated inhabitants, and widens and humanises the interests of specialists.

Dr. W. M. Tattersall (Museums Association) agreed with Dr. Hoyle as to the necessity and importance of local museums, and suggested closer co-operation between the museum authorities and the members of the local societies with a view to the better organisation of the collecting of local specimens. The museum should be the headquarters of all the local societies, and the curator could, by a little organisation, make use of them to provide him with collections of local specimens and at the same time increase the value of their work, at present often spasmodic and aimless. He emphasised the value of local collections as a stimulus to local workers and as an educational asset of the highest utility to the people of the district in which the museum was situated While recognising the great value of circulating collections for the use of schools, he was of opinion that the provision of such collections came more properly within the province of the local Education Committee, or, better still, should be organised by a Central Authority such as the Board of Education.

Professor Geddes called attention to the 'Survey of Greater London' now in progress, under the auspices of the Architects' War Committee of the Royal Institute of British Architects, at their premises, 9 Conduit Street, W., under the direction of Mr. H. V. Lanchester and Mr. E. F. G. Jemmett, F.R.I.B.A., from the latter of whom particulars may be obtained. A similar survey is now beginning for Greater Manchester under the direction of Professor Patrick Abercrombie, Department of City Design, University of Liverpool, and other kindred surveys are also under consideration for other important centres; and

in this way it may reasonably be hoped that a more and more comprehensive study of our leading cities and city-regions may before long be in active progress, and from all points of view. As regards co-operation with these surveys by museums and local natural history societies, particulars can be obtained from Mr. R. Maynard, the Curator of the Museum, Saffron Walden, Essex.

Alderman ARTHUR BENNETT (Warrington Society) said that he should like to emphasise in the strongest possible way the desirability of securing and preserving cinema films of all important local and national events, which, if they could be made sufficiently permanent, would be of lasting historical value. He also cordially agreed with Professor Geddes in his plea for a civic survey of every town and district in the country. The Chairman might be interested to know that Dr. Percival and Dr. Barnes, who were largely instrumental in forming the Manchester Literary and Philosophical Society, were born in Warrington, and that Warrington could boast the earliest free rate-supported museum and library in the United Kingdom, both of which were singularly rich in local relics. The Society he represented, in addition to its various other objects, existed to maintain the Warrington Academy as a local museum specially devoted to the commemoration of the golden age of Warrington's history, and its collection was limited to books, pictures, and relics which were either directly associated with the Academy or reflected lustre on the annals of the town. He believed that there was ample room, in many places, for specialised local museums on these lines.

Mr. F. W. ASH (North Staffordshire Field Club) said that local museums might be divided into two classes, the objects of which are largely opposite. In the one kind the exhibits have local relations, but are for the benefit of visitors and the general public (example : a local archæological collection). In the other kind the collection may be of a *general* nature, and intended for the benefit of *local* students (example : a natural history collection. It is questionable if any particular purpose is served (in many cases) by a zoological collection limited to specimens from a political boundary such as that of a county.

Mr. COLLIN BROOKS (Southport Literary and Philosophical Society) said that the point which struck him, as representing a philosophical society not concerned with experimental or pure science, was that the majority of local museums were the property of a township, and, reverting to John Ruskin's analogy, in considering the collection as the possession of an individuality, the centralisation of exhibits to a national museum was hardly a right or sound procedure. There was some danger of a mistake in phraseology. The meaning of the words 'the advancement of science' was ambiguous. They of the British Association construed it into the advancement of the results of science : a township, he imagined, would merely interpret it as the broadening of the basis and membership of their scientific community. As one not personally concerned in museum control, he was strongly in favour of the decentralisation of exhibits to purely local habitations.

Mr. WILLIAM WHITAKER was of opinion that the division of museums into national and local is hardly enough. There is a great class between, consisting of the museums of great towns, which, though not national, are by no means merely local.

Mrs. FORBES JULIAN (Torquay Natural History Society) also spoke.

The CHAIRMAN (Institute of Mining Engineers) stated that, during his term of office as Chairman of the Trustees of the Calcutta Museum, the question of balancing the claims of a national, as against those of provincial, museums passed through an acute stage; and, according to the lessons then learnt, he considered that any provincial museum should be permitted to retain valuable specimens, including 'types,' whenever, in the opinion of the Museums Association, its government and curatorship are satisfactorily stable. It would be quite easy to define and to enforce, by periodical inspection, a satisfactory standard of management. Local authorities should be given to understand that unique and reference specimens are not their private property, but that they are trustees responsible to the scientific world. So long as the safety of a reference specimen be reasonably assured it should not be removed from the local museum; for local pride, due to the possession of valuable materials, helps the healthy spread of interest

in science. It is as easy and as important to legislate for the preservation of specimens of scientific value as for the preservation of ancient monuments.

The thanks of the Conference were given to Dr. Hoyle.

The Conference then adjourned.

At a second meeting of the Conference, which was held on Friday, September 10, mention was made of the interest which had been aroused by the suggestions contained in the Chairman's address, and Mr. WHITAKER, the Vice-Chairman, read the following explanatory remarks :

The existing practice prevents a suitable classification of papers, and affords no guarantee to research workers that the papers have been considered by any body observing a constant and recognised standard.

It is the opinion of many that the progress of science would be greatly facilitated by the adoption of a system such as that suggested by the Chairman—namely, by a form of limited control by the Royal Society in the matter of publications, or by an independent federation of the non-specialised scientific societies. By either of these two systems it would be possible for original papers of scientific value to be made more accessible to research workers, as such papers would then be suitably grouped by subjects, and would appear in a recognised serial accessible in all important reference libraries.

With regard to the proposal to form an independent federation of non-specialised societies, there is the obvious objection that such an institution would add one more to an already embarrassingly large variety of papers. Any scheme also of the kind would require the organisation of another controlling Council, necessarily composed of unequal constituents, the working of which would present difficulties on account of the wide geographical distribution of the societies.

On the other hand, the publications of the Royal Society are already established, and are recognised throughout the world as authoritative. The machinery for controlling such publications is already organised and in working order, additional advantage being gained by the fact (1) that the sectional committees of the Royal Society are independent of local influences, and (2) that the additional cost of the publications would be small compared with that of establishing a new serial, appropriately divided into parts, to suit the natural subdivisions of science. From the financial point of view, therefore, it would be more economical, even if the provincial societies had to bear the additional cost to the Royal Society, to adopt the system suggested by the Chairman.

Comments were made by many of the delegates present, including Sir Daniel Morris (Bournemouth Natural Science Society), Sir Eustace Gurney and Mr. Alfred W. Oke (Brighton and Hove Natural History Society and South-Eastern Union of Scientific Societies), Mr. Wilfred Mark Webb (the Selborne Society), Mr. Harry Sowerbutts (Manchester Geographical Society), Mr. Henry Coates (Perthshire Society of Natural Science), and Miss Crosfield (Holmesdale Natural History Society). Mr. H. W. DAVIES (Somerset Archæological and Natural History Society) thought that it might be advisable to bring the matter before the Corresponding Societies Committee before a further step was taken. The following resolution was then passed : 'That this Conference of Delegates invites the attention of the Corresponding Societies Committee to the Chairman's opening address, in which suggestions are made for reforming the existing varied and unorganised practice of publishing original papers.'

The suggestion that Sir Thomas Holland should be asked to join the Corresponding Societies Committee was enthusiastically received.

The second subject for discussion, namely 'Colour Standards,' was introduced by Mr. J. RAMSBOTTOM in the following paper :—

During the past ten years there have been published three schemes of colours : Oberthur and Dauthenay's 'Répertoire de Couleurs,' Klincksieck and Valette's 'Code des Couleurs,' and Ridgway's 'Color Standards and Color Nomenclature.' These three works have been adopted by different naturalists, and it has seemed to the British Mycological Society that the question of a colour standard is one that might profitably be brought to the notice of the Corresponding Societies of the British Association.

As everyone who has had to deal with colour in the natural sciences realises, there are two fundamental difficulties : (1) the difficulty of understanding what

is intended by any colour-term used in a description; (2) the difficulty which any worker himself has of satisfactorily naming the colours in a species under discussion.

It is obvious that these difficulties have not come forward suddenly during the present century, and in the few days at my disposal I have attempted to trace out various previous attempts to get over them. In this way it would appear that the requisites of a standard could best be appreciated.

The earliest effort to define colours from the naturalist's standpoint to which I have found a reference is in an Appendix to Charleton's 'De Nominibus Animalium,' 1677. This author realises the almost infinite varieties of colours, and the difficulty of translating classical names into English idiom. He divides the colours up into groups: white, black, yellow, blue, etc. He gives Latin names for the colours, *e.g.*, *Psittaceus* is described as 'Poppin-jay-green, such as the green of parrots, which in old English were call'd Pope-jayes, quasi Priests-jayes.' This method of describing colour by referring it to some natural object has always been common with men of science, and has much to commend it. When one gets away from common objects, however, in the definition of colour, obvious objections arise. The more perfect the scheme in any branch of science the more difficult it is of general application.

The alternative method is to have samples of colour for comparison. It is to such scales we must look if we are to have a satisfactory scheme of denoting colours. Such colour charts have been brought forward at different times. The first colour chart of this description appears to have been published in Hayne's 'Termini Botanici Iconibus Illustrati,' 1807. There are thirty-six samples of colour which have Latin names appended. In the text the terms are explained, with examples where possible, and the German equivalent given. Next, Werner's 'Nomenclature of Colours,' as introduced by Patrick Syme, was published in 1814; a second edition of this work was published seven years later. The first edition has 108 tints; the second 110. The introduction gives the method by which each colour was prepared. The samples are very small (half-inch square), and pasted ten on a page. The name of the colour is given, and examples of the colour where possible from the animal, vegetable, and mineral kingdoms. Thus: *Wine yellow*; body of silk moth; stamina of honeysuckle; pale Brazilian topaz. Most of the colours have by this time considerably altered, and, on comparing the two editions, it is seen that many of the colours, with the same names, are quite different. This scheme met with some success, and was used in Barton's 'Flora of North America,' 1821.

In 1815 Mirbel, in his 'Elémens de Botanique,' gave a chart of eighty-three tints, the only explanation given being a naïve statement that by its aid any colour whatever can be matched; a statement which appears particularly ridiculous now that all the whites have turned black.

Another scheme which may be mentioned is that of Haytor, which is appended to Sinclair's 'Hortus Ericaeus Woburnensis,' 1825, one of the well-known Woburn monographs. An account of the origin of the scheme is given in a letter by Haytor to the Duke of Bedford. Sinclair had 'lamented much that no work existed to render clear and definite all communications on the subject of any new or rare bloom. . . . In attempting at present to describe the colour of any given flower, the term *red*, he remarked, was applied to so many blossoms that it was impossible to define precisely what was meant by it: and, to give me an evidence of the want he complained of, he took me to several flowers, generally called *red*, but varying so much that, to my eye as a painter, they each demanded a different appellation for their colour.' He adds that matters are made worse by adding the termination *-ish*, and arriving at such indefinite but common terms as 'reddish' and 'greenish.' A comparison of the colour descriptions of the same varieties in present-day florists' catalogues shows clearly that matters are quite as bad as they were a hundred years ago; and the entomologist's *testaceus* and the mycologist's *ferrugineus* show that Latin terms are used with just as much levity. In Haytor's scheme 272 tints are arranged in a circle in the form of a mariner's compass, and the nomenclature is also nautical, *e.g.*, red, red by purple. Two gradations are appended, one showing the range from black to white, the other from brown to white. The scheme does not appear to have been at all successful.

Another arrangement of general application is that of Hay, 'A Nomenclature of Colours applicable to the Arts and Natural Sciences, to Manufactures, and other purposes of General Utility,' 1845. The second edition has forty plates, each with six one-and-a-half-inch-sided triangles of colour pasted in. The samples were very evenly painted, and very little fading appears to have taken place. The introduction gives the author's theories of colour, and the arrangement, which is difficult to follow, is based upon these. The nomenclature, in which 'tempered green hue' and such like appear, was also probably a factor against any general adoption by naturalists.

Before this time Chevreul, Directeur des Teintures à la Manufacture Nationale des Gobelins—the national manufactory of tapestry in Paris—began to devise a classification of colours. His first discussion, 'La Loi du Contraste simultané des Couleurs,' appeared in 1839. A full account of his scheme, and its application, is given in a memoir of 944 pages ('Mém. Acad. Sci.,' Paris, 1861, 'Exposé d'un Moyen de définir et de nommer les Couleurs'). This method, which it would take too long to describe, is still used at the national manufactory of tapestry, and is the basis of the modern French colour schemes. Theoretically, over 14,000 different colours, tones, shades, and tints are obtainable, but in practice a much smaller number suffices. In 1855 Digeon published a set of ten charts, 'Cercles Chromatiques de M. E. Chevreul.' The circles are divided into seventy-two sectors, and there is a gradual gradation from red through orange red to orange, and so on. The charts have different percentages of black added, from ·1 to ·9. Thus there are 720 different shades. The name of the colour is denoted by giving the number of the chart and of the sector. Chevreul's full scheme is made more complete by having different intensities of colour.

Radde's 'Internationale Farben Skala,' 1877, consists of fifteen cards. The first gives the forty-two cardinal tones of the arrangement; the remainder gives the range of these from *a* to *v*, thus comprising about 800 tints. A sliding block permits of the isolation of adjoining colours. The cards are inconvenient to use; the colours are printed on inferior paper, and are without names. The scheme has been used by mineralogists.

Since this date many different colour schemes have appeared, some of which have been drawn up without any reference to previous attempts, and have repeated faults which otherwise might have been guarded against. In 1886 appeared the book which has been most used until recent years, Ridgway's 'A Nomenclature of Colors for Naturalists; and Compendium of Useful Knowledge for Ornithologists.' Two of Ridgway's statements are much to the point. 'Popular and even technical natural history demands a nomenclature which shall give a standard for the numerous hues, tints, and shades which are currently adopted, and now form part of the language of descriptive natural history.' Again: 'Popular nomenclature of colors has of late years, especially since the introduction of aniline dyes and pigments, become involved in almost chaotic confusion through the coinage of a multitude of new names, many of them synonymous, and still more of them vague, or variable in their meaning. These new names are far too numerous to be of any practical utility, even were each one identifiable with a particular fixed tint.' In this book there are 186 named colours painted into rectangles 1-inch $\times \frac{1}{2}$-inch. The colours in the copies of this book which I have examined are not nearly so even as in Hay's book, or in the more recent works. Passing on we come to Saccardo's 'Chromotaxia' of fifty samples, with a polyglot nomenclature. This appeared in 1891. In this year also a series of forty colours was given in Constantin and Dufour's 'Nouvelle Flore des Champignons' to illustrate the terms used in the descriptions, and the symbols in the drawings of fungi.

'A Chart of Correct Colors of Flowers' appeared in *The American Florist* for 1895. This was arranged by Matthews, and consisted of a single sheet with thirty-six squares of colour, with a very simple nomenclature.

Another American horticultural chart appeared about 1900 with the title 'Color Guide for Florists.' This was arranged by Köhn, and contains 140 colour shades. A scheme which has been used by some naturalists is 'The Prang Standard of Color.' This contains 1,152 examples, and is remarkable for its cheapness, costing only fifty cents. Unfortunately the colours are not named.

The 'Répertoire de Couleurs'[1] of Oberthur and Dauthenay, published by the French Chrysanthemum Society in 1905, contains over 1,400 samples. The colours are named in almost every case in several languages. The great objection to this work is its size.

The 'Code des Couleurs'[1] of Klincksieck and Valette appeared in 1908. It is a convenient little book, containing 720 specimens of colour, but they are merely numbered. The work was prepared principally for the use of mycologists. Both the Répertoire and the Code are arranged on a simplification of Chevreul's method.

Ridgway's 'Color Standards and Color Nomenclature'[1] was issued in 1912. The 1,115 samples are named, though some of the names are not such that would appear suitable for a standard nomenclature.

Added to these numerous charts are those of different manufacturers and those drawn up by artists, &c. Even philatelists have their colour schemes.

Lovibund's tintometer is far too complicated and too expensive for ordinary use in the description of specimens. The fact that so many attempts have been made to draw up colour schemes shows clearly that a standard of colours is necessary, as is also a standard of nomenclature. Naturalists could decide to adopt the French Chrysanthemum Book or Ridgway. The former was adopted by the Royal Horticultural Society, but recently it has been somewhat ousted amongst horticulturists by the American book, principally owing to the latter being much more convenient to use. On inquiry I find that amongst naturalists these two works are the most frequently used.

The 'Code des Couleurs,' though very convenient to use, suffers from the fact that the colours are *unnamed*.

But the Chrysanthemum Book costs a guinea and Ridgway thirty-five shillings! In most branches of science, colour is not regarded with so much favour as to demand such an outlay, even for a satisfactory range of tints. Colour in many organisms varies so much under different conditions that it is not regarded as a specific character. What seems to be required is, not a scale to record the minutest variation, but merely one that will add definiteness to the description of the general range in colour. Probably a scale with about 200 samples would be found sufficient for ordinary use. In such branches of science as horticulture, mycology, ornithology, &c., where colour is of more importance, additional colours could be interpolated. If anyone interested in any particular science will look through the colour charts which are here, he will find very many colours which will seem more or less useless in that science, and in certain cases will find that there are not sufficient of certain grades. As an example of what I mean: Horticulturists could dispense with a large number of the colours given in Ridgway; mycologists certainly can omit page after page. On the other hand, there is already a movement on foot to produce another edition of Ridgway, with more tones of such colours as 'salmon-pink.' My own opinion is that it is not wise to attempt to make such a complete range as would satisfy every possible use. The way out of the difficulty is obviously that of having a general scheme with a small number of colours; then additional editions may be provided in those subjects where there is special demand, or separate sheets of the variations of the original colours of the general scheme could be prepared. If, as one would hope, a standard of colours should be adopted in all branches of science, art, and industry, the latter scheme would appear to be the more feasible. The advantages of having a universal standard of colours are so obvious that one would expect the very great difficulties of obtaining such would not prove insurmountable if the matter were approached in a proper manner.

The earlier schemes lacked one of the primary essentials of colour standards in that they were not standards at all. Ridgway's scheme is the only one in which the colours have been standardised by physical methods, and hence the only one in which the colours can be reproduced with accuracy. In the suggested standard of colours, it would be the work of physicists, by means of such apparatus as Michelin's grating and Maxwell's disc, to give us the definition of our colours. In this way the defect from which all colours suffer to some

[1] Copies of these works were shown at the meeting.

extent—*i.e.*, fading, could be brought to its lowest terms of inconvenience, though the samples of colour published would be made in such a way that fading would be guarded against as far as modern colour chemistry makes it possible.

The colours in the primary scheme should be named. No sane naturalist wishes to talk in such symbols as '4OJ8t.' On the other hand, the same naturalist would not wish to use many of the colour terms even in Ridgway, who rightly objects to such absurd names as 'ashes of roses' and 'elephant's breath.' The usual method of assigning colours to common natural objects should be followed, as far as is possible, in the primary scheme. Whether in the more complicated schemes every colour, shade, tint, and hue should receive a name is a matter for consideration. I am informed that the colours supplied to artists under the same name are not always the same even from the same firm. This is ridiculous, if a colour name means anything. A standard of colours would seem to give some protection.

Unfortunately, most of us suffer from the fact that we have received no colour education. This has probably been one of the principal reasons why many people have not adopted a colour chart: the constituents of a given colour are not appreciated, and hence the difficulty of matching it. More attention seems to be paid to this subject in America than in this country, judging from the literature on the subject.

A further point is that a colour standard should be cheap. Charts of colour samples are supplied gratis by every dealer in artist's colours, wall distempers, &c.; yet the naturalist has to expend a considerable sum for a scheme, eighty per cent. of which is probably useless to him, and other workers in his subject may be using other charts. There seems no apparent reason why a suitable series of standard colours should not be published at a shilling or so. There is no need for much letterpress dealing with the theory of colour, but there should be a few notes on the best way of comparing colours, having regard to texture of surface and various optical illusions.

To summarise:—

1. For ordinary use there should not be too many colours.
2. A fair-sized, even sample of colour should be given.
3. The colour must be as durable as can be obtained.
4. The colour must be standardised by modern physical and chemical methods.
5. Colours to be interpolated in the special cases where necessary.
6. The colours must be named in the primary list, popular names being used where possible, and common objects referred to when suitable. If an international scheme be adopted, there would necessarily be a polyglot nomenclature.
7. The standard must be cheap, well arranged, and in book form.

In conclusion I would express my thanks to the numerous naturalists with whom I have discussed the question of a colour standard.

Some discussion took place, and Mr. Greevz Fysher (Leeds Naturalists' Club and Scientific Association) pointed out the importance of colour standards from a commercial point of view. As it was the general opinion that the matter did not come within the province of any one of the Sections of the British Association, it was referred to the Corresponding Societies Committee.

The meeting closed with a vote of thanks to Mr. Ramsbottom.

The following Delegates attended the Conference and signed the attendance book, their attendance being indicated by the figures 1 2, which refer respectively to the first and second meeting.

AFFILIATED SOCIETIES.

1 2	Andersonian Naturalists' Society. . . .	M. A. B. Gilmour, F.Z.S.
1 2	Berwickshire Naturalists' Club	G. P. Hughes, F.R.G.S.
1 2	Bournemouth Natural Science Society . .	Sir Daniel Morris, K.C.M.G.

1	2	Brighton and Hove Natural History and Philosophical Society	Alfred W. Oke, F.G.S.
	1	British Mycological Society	Miss A. Lorrain Smith, F.L.S.
	1	Buchan Club	J. F. Tocher, D.Sc.
	1	Caradoc and Severn Valley Field Club	Prof. W. W. Watts, F.R.S.
	1	Cardiff Naturalists' Society	Principal Griffiths, F.R.S.
	1	Cornwall Royal Polytechnic Society	W. Lloyd Fox.
1	2	Croydon Natural History and Scientific Society	W. Whitaker, F.R.S.
1	2	Dorset Natural History and Antiquarian Field Club	Sir Daniel Morris, K.C.M.G.
1	2	Edinburgh Field Naturalists' and Microscopical Society	R. C. Millar.
1	2	Edinburgh Geological Society	R. C. Millar.
1	2	Essex Field Club	Joseph Wilson.
	1	Glasgow Geological Society	Prof. J. W. Gregory, F.R.S.
1	2	Glasgow Natural History Society	Mrs. Ewing.
	1	Glasgow Royal Philosophical Society	C. R. Gibson, F.R.S.E.
	1	Hampshire Field Club and Archæological Society	W. Dale, F.S.A.
	1	Hertfordshire Natural History Society and Field Club	G. W. Lamplugh, F.R.S.
1	2	Holmesdale Natural History Club	Miss M. C. Crosfield.
	1	Hull Geological Society	T. Sheppard, F.G.S.
	1	Hull Scientific and Field Naturalists' Club	T. Sheppard, F.G.S.
1	2	Institution of Mining Engineers	Sir Thomas Holland, K.C.I.E.
	1	Liverpool Engineering Society	Prof. E. W. Marchant, D.Sc.
	2	Liverpool Geographical Society	A. Ellis Cookson.
	2	London: Quekett Microscopical Club	C. F. Rousselet.
1	2	London: Selborne Society	W. M. Webb, F.L.S.
1	2	Manchester Geographical Society	Harry Sowerbutts
1	2	Manchester Geological and Mining Society	William Watts, F.G.S.
1	2	Manchester Microscopical Society	Mark L. Sykes.
1	2	Midland Counties Institution of Engineers	Sir Thomas Holland, K.C.I.E.
	1	Museums Association	W. M. Tattersall, D.Sc.
1	2	Norfolk and Norwich Naturalists' Society	Sir Eustace Gurney.
	1	North Staffordshire Field Club	F. W. Ash.
	1	Northumberland, Durham, and Newcastle-on-Tyne Natural History Society	N. H. Martin, F.R.S.E.
1	2	Perthshire Society of Natural Science	Henry Coates, F.R.S.E.
1	2	Rochdale Literary and Scientific Society	J. R. Ashworth, D.Sc.
	1	Sheffield Naturalists' Club	W. Parkin.
	2	Somersetshire Archæological and Natural History Society	H. N. Davies, F.G.S.
1	2	South-Eastern Union of Scientific Societies	Alfred W. Oke, F.G.S.
	1	Southport Literary and Philosophical Society	Collin Brooks.
1	2	Torquay Natural History Society	Mrs. Forbes Julian.
	1	Yorkshire Geological Society	T. Sheppard, F.G.S.
	1	Yorkshire Naturalists' Union	T. Sheppard, F.G.S.
1	2	Warrington Literary and Philosophical Society	J. S. Manson, M.D.

ASSOCIATED SOCIETIES.

	1	Balham and District Antiquarian and Natural History Society	Sir Edward Brabrook, C.B.
1	2	Ealing Scientific and Microscopical Society	J. Stark Browne, F.R.A.S.
1	2	Hastings and St. Leonards Natural History Society	George Wilson.
	2	Hawick Archæological Society	C. J. Wilson.
	1	Leeds Naturalists' Club and Scientific Association	Greevz Fysher.
	1	Lewisham Antiquarian Society	Sir Edward Brabrook, C.B.
1	2	School Nature Study Union	Mrs. White, D.Sc.
	1	Teign Naturalists' Field Club	John S. Amery.
	1	Warrington Society	Arthur Bennett.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1915–1916.

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 . .	Royal Technical College, Glasgow. Harry G. Cumming	240	2*s.* 6*d.*	2*s.* 6*d.*	Annals, occasionally.
Ashmolean Natural History Society of Oxfordshire, 1828	Miss A. L. Stone, 2 St. Margaret's Road, and Rev. C. F. Thornewill, 15 St. Margaret's Rd., Oxford	300	None	5*s.*	Report, annually.
Belfast Natural History and Philosophical Society, 1821	Museum, College Square. J. M. Finnigan.	200	None	1*l.* 1*s.*	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863 . . .	Museum, College Square	330	5*s.*	5*s.*	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831 . . .	Rev. J. J. M. L. Aiken, B.D., Manse of Ayton, Berwickshire	300	10*s.*	7*s.* 6*d.*	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Alfred Cresswell, Birmingham and Midland Institute, Paradise Street, Birmingham	131	None	10*s.* 6*d.* and 5*s.*	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Avebury House, Newhall Street, Birmingham. W. H. Foxall, F.R.G.S.	211	None	1*l.* 1*s*	Proceedings, annually.
Bournemouth Natural Science Society, 1903 .	R. A. de Paiva, 13 Carysfort Road, Bournemouth	458	None	10*s.*	Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	J. Colbatch Clark, 9 Marlborough Place, Brighton	140	None	10*s.*	Report, annually.
Bristol Naturalists' Society, 1862	Dr. O. V. Darbishire, The University, Bristol .	150	5*s*	10*s* and 5*s.*	Proceedings, annually.
British Mycological Society, 1896	Carleton Rea, 34 Foregate Street, Worcester .	137	None	10*s.*	Transactions, annually.
Buchan Club, 1887	J. F. Tocher, D.Sc., Crown Mansions, Union Street, Aberdeen	180	5*s.*	5*s.*	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	A. Slator, D.Sc., 174 Ashley Road, Burton-on-Trent	200	None	6*s*	Report, annually; Transactions, occasionally.
Canada, Royal Astronomical Society of, 1884 .	Canadian Institute Building, Toronto. J. R. Collins	550	None	2 dollars	Journal, bi-monthly.
Caradoc and Severn Valley Field Club, 1893 .	H. E. Forrest, 37 Castle Street, Shrewsbury .	196	5*s.*	5*s.*	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Dr. Owen L. Rhys, 26 Windsor Place, Cardiff .	500	None	12*s.* 6*d.*	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Grosvenor Museum, Chester. G. P. Miln . .	980	None	5*s.* and 2*s.* 6*d.*	Report and Proceedings, annually.
Cornwall, Royal Geological Society of, 1814 .	The Museum, Public Buildings, Penzance. John B. Cornish	82	None	1*l.* 1*s.*	Transactions, annually.
Cornwall, Royal Institution of, 1818 . . .	Henry Jenner, F.S.A., County Museum, Truro .	190	None	1*l.* 1*s.*	Journal, annually.
Cornwall, Royal Polytechnic Society, 1833 . .	E. W. Newton, 4 Cross Street, Camborne, Cornwall	350	None	10*s.*	Report, annually.
Cotteswold Naturalists' Field Club, 1846 . .	L. Richardson, 33 Cecily Hill, Cirencester . .	121	1*l*	15*s.*	Proceedings, annually.
Croydon Natural History and Scientific Society, 1870	Public Hall, Croydon. Miss G. Bigby . .	130	None	10*s.*, 5*s.*, and 2*s.* 6*d.*	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Rev. Herbert Pentin, M.A., St Peter's Vicarage, Portland	400	10*s.*	10*s.*	Proceedings, annually.
Dublin Naturalists' Field Club, 1885 . . .	C. B. Moffat, B.A., 23 Gardiner's Place, Dublin .	75	5*s.*	5*s.*	'Irish Naturalist,' monthly; Report, annually.

Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	G. W. Shirley, Ewart Public Library, Dumfries .	414	None	7*s.* 6*d.*	Transactions and Proceedings, annually.
Durham, University of, Philosophical Society, 1896	J. A. Smythe and E. M. Eden, Armstrong College, Newcastle-on Tyne	200	None	10*s.* and 5*s.*	Proceedings, half-yearly.
East Anglia, Prehistoric Society of, 1908 . .	W. G. Clarke, 12 St. Philip's Road, Norwich .	225	None	5*s.*	Proceedings, annually.
East Kent Scientific and Natural History Society, 1857	A. Lander, 17 High Street, Canterbury . .	60	None	10*s.* and 5*s.*	Transactions, annually.
Eastbourne Natural History, Photographic, and Literary Society, 1867	Miss Jay, Technical Institute, Eastbourne .	180	2*s.* 6*d.*	5*s.*	Transactions and Journal, quarterly.
Edinburgh Field Naturalists' and Microscopical Society, 1869	Allan A. Pinkerton, 20 George Street, Edinburgh	225	None	5*s.*	Transactions, annually.
Edinburgh Geological Society, 1834 . . .	India Buildings, Edinburgh. W. T. Gordon .	250	10*s.* 6*d.*	12*s.* 6*d*	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	H. B. Mackintosh, Redhythe, Elgin . . .	149	None	5*s.*	Transactions, occasionally.
Essex Field Club, 1880	Essex Museum of Natural History, Romford Road, Stratford. W. Cole	300	None	15*s.*	'Essex Naturalist,' half-yearly.
Glasgow, Geological Society of, 1858 . . .	Peter Macnair, F.R.S.E., and H. R. J. Conacher, 207 Bath Street, Glasgow	197	None	10*s.*	Transactions and Proceedings, annually.
Glasgow, Natural History Society of, 1851 . .	Alex. Ross, 409 Great Western Road, Glasgow .	264	None	7*s.* 6*d.*	'Glasgow Naturalist,' quarterly.
Glasgow, Royal Philosophical Society of, 1802 .	Prof. Peter Bennett, 207 Bath Street, Glasgow .	1,000	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually.
Hampshire Field Club and Archæological Society, 1885	W. Dale, F.S.A., F.G.S., The Lawn, Archer's Road, Southampton	250	5*s.*	10*s.* 6*d.*	Proceedings, annually.
Hampstead Scientific Society, 1899 . . .	C. O. Bartrum, B.Sc., and R. W. Wylie, M.A., 32 Willoughby Road, Hampstead, N.W	362	None	Minimum 5*s.*	Report and Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	John Hopkinson, F.L.S., Weetwood, Watford .	164	None	10*s.*	Transactions, one or two parts annually.
Holmesdale Natural History Club, 1857 . .	Mrs. Perrin, Clears Corner, Reigate . . .	67	None	10*s.* and 5*s.*	Proceedings, occasionally.
Hull Geological Society, 1889	J. W. Stather, F.G.S., Newland Park, Hull . .	70	None	5*s.*	Transactions, occasionally.
Hull Scientific and Field Naturalists' Club, 1886 .	T. Stainforth, B.A., The Museum, Hull . .	140	None	5*s.*	Transactions, annually.
Institution of Mining Engineers, 1889 . . .	Percy Strzelecki, 39 Victoria Street, London, S.W.	3,600	None	None	Transactions, monthly.
Ipswich and District Field Club, 1907 . . .	F. J. Brinkley, 25 Bedford Street, Ipswich . .	90	None	2*s.* 6*d.*	Journal, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	W. Lawson, Dr. N. M. Falkiner, and Herbert Wood, 93 Stephen's Green, Dublin	80	None	1*l.*	Journal, annually.
Leeds Geological Association, 1873 . . .	E. Hawkesworth, Cross Gates, Leeds . . .	119	None	5*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Corporation Museum. F. B. Lott, 7 Stoneygate Avenue, Leicester	291 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s.*6*d*	Transactions, annually.
Lincolnshire Naturalists' Union, 1893 . . .	Arthur Smith, F.L.S. City and County Museum, Lincoln	112	None	5*s.*	Transactions, annually.
Liverpool Biological Society, 1886 . . .	J. A. Clubb, D.Sc., Free Public Museum, Liverpool	80	None	1*l.* 1*s.*	Proceedings and Transactions, annually.
Liverpool Botanical Society, 1906 . . .	Miss M. B. Barr, 25 Deane Road, Fairfield, Liverpool	118	None	5*s.*	Proceedings, biennially; Transactions, occasionally.
Liverpool Engineering Society, 1875 . . .	T. R. Wilton, M.A., 1 Crosshall Street, Liverpool	599	None	1*l.* 1*s.*, 10*s.* 6*d.*, and 5*s.*	Transactions and Report, annually.
Liverpool Geographical Society, 1891 . . .	A. Ellis Cookson, 14 Hargreave's Buildings, Liverpool	550	None	Members 1*l.* 1*s.*; Associates 10*s.*6*d.*	Transactions and Report, annually.
Liverpool Geological Society, 1858 . . .	Royal Institution. T. A. Jones	75	None	10*s.* 6*d.*	Proceedings, annually.
London: Quekett Microscopical Club, 1865. .	Jas. Burton, 8 Somali Road, West Hampstead, N.W.	450	None	10*s.*	Journal, half-yearly.

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
London: Selborne Society, 1885 . . .	42 Bloomsbury Square, W.C. W. M. Webb, F.L.S.	2,780	None	5*s.*	'Selborne Magazine,' monthly.
Man, Isle of, Natural History and Antiquarian Society, 1879	W. Percy Cowley, Ramsey, Isle of Man . .	276	2*s.* 6*d.*	7*s.* 6*d.* and 5*s.*	Proceedings and Transactions, annually.
Manchester Geographical Society, 1884 . .	E. Steinthal and H. Sowerbutts, 16 St. Mary's Parsonage, Manchester	708	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Journal, quarterly.
Manchester Geological and Mining Society, 1838	5 John Dalton Street, Manchester. Noah T. Williams	400	None	2*l.* 2*s.*, 1*l.* 5*s.*, and 1*l.*	Transactions of Inst. of Mining Engineers, monthly.
Manchester Microscopical Society, 1880 . .	Grand Hotel, Aytoun Street, Piccadilly, Manchester. Frederick Dishley	180	5*s.*	6*s.*	Transactions and Report, annually.
Manchester Statistical Society, 1833 . . .	F. Vernon Hansford, 3 York Street, Manchester	161	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	J. C. Aisop, M.A., Marlborough College . .	150	1*s.*	3*s.*	Report, annually.
Midland Counties Institution of Engineers, 1871	G. Alfred Lewis, M.A., Midland Road, Derby .	375	1*l.* 1*s.*	2*l* 2*s.* and 1*l.*	Transactions of Institution of Mining Engineers, monthly.
Museums Association, 1889	E. E. Lowe, B.Sc., Museum and Art Gallery, Leicester	Members (Insts.) 111 Associates (Persons) 119	None	21*s.*	Museums Journal, monthly.
			None	10*s.* 6*d.*	Museums Directory, occasionally.
Norfolk and Norwich Naturalists' Society, 1869 .	S. H. Long, M.D., 37 St. Giles Street, Norwich .	283	None	7*s.* 6*d*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	Neville Hall, Newcastle-upon-Tyne. Allan Cordner	1,242	None	25*s.* and 42*s.*	Transactions of Inst. of Mining Engineers, monthly.
North Staffordshire Field Club, 1865 . . .	W. Wells Bladen, Stone, Staffs.	645	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	H. N. Dixon, M.A., 17 St. Matthew's Parade, Northampton	230	None	10*s.*	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829 . .	Hancock Museum, Newcastle-on-Tyne C. E. Robson and J. A. Richardson	415	None	21*s.*	Transactions, annually.
Nottingham Naturalists' Society, 1852 . .	Prof. J. W. Carr, M.A., University College, Nottingham	111	2*s.* 6*d.*	5*s.*	Report and Transactions, annually.
Paisley Philosophical Institution, 1808 . .	J. Gardner, 3 County Place, Paisley . . .	548	5*s.*	7*s.* 6*d.*	Report and Meteorological Observations, annually.
Perthshire Society of Natural Science, 1867 .	Tay Street, Perth. S. T. Ellison	324	None	5*s.* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878 .	J. Reginald Ashworth, D.Sc., 55 King Street South, Rochdale	240	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878 . . .	Edmund Page, 42 Balmoral Road, Gillingham, Kent	110	None	5*s.*	'Rochester Naturalist,' quarterly.
Sheffield Naturalists' Club, 1870 . . .	O. Bradshaw, Public Museum, and A. Brittain, 47 Bank Street, Sheffield	105	None	5*s.*	Report, bi-annually; Proceedings, occasionally.

Somersetshire Archæological and Natural History Society, 1849	The Castle, Taunton. Rev. F. W. Weaver, Rev. E. H. Bates Harbin, O. Tite, and H. St. George Gray	910	10*s.* 6*d.*	Minimum 10*s.* 6*d.*	Proceedings, annually.
South Africa, Royal Society of, 1906 . . .	G. M. Clark, South African Museum, Cape Town	207	None	2*l.*	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	William Martin, LL.D., F.S.A., 2 Garden Court, Temple, E.C.	about 13,000	None	Minimum 5*s.*	'South-Eastern Naturalist,' annually.
Southport Literary and Philosophical Society .	A. H. Garstang, 82 Forest Road, Southport .	217	None	7*s.* 6*d.*	Proceedings, occasionally.
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	G. D. Smith, 3 Newhall Street, Birmingham .	150	1*l.* 1*s.* and 10*s.* 6*d.*	42*s.* and 21*s.*	Transactions of Institution of Mining Engineers, monthly.
Torquay Natural History Society, 1844 . .	Harford J. Lowe, F.G.S., The Museum, Torquay	171	10*s.* 6*d.*	1*l.* 1*s.*	Journal, annually.
Tyneside Geographical Society, 1887 . . .	Geographical Institute, St. Mary's Place, Newcastle-on-Tyne. Herbert Shaw, B.A.	1,000	None	21*s.* and 10*s.*	Journal, quarterly.
Vale of Derwent Naturalists' Field Club, 1887 .	J. E. Patterson, 2 East Avenue, Benton, Newcastle-on-Tyne	150	None	2*s.* 6*d.*	Transactions, occasionally.
Warrington Literary and Philosophical Society, 1870	J. S. Manson, M.D., 8 Winmarleigh Street, Warrington	137	None	5*s.*	Proceedings, biennially.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Museum, Warwick. C. West, Cross Cheaping, Coventry	70	2*s.* 6*d.*	5*s.*	Proceedings, annually
Woolhope Naturalists' Field Club, 1852 . .	Woolhope Club Room, Free Library, Hereford. T. Hutchinson	220	10*s.*	10*s.*	Transactions, occasionally.
Worcestershire Naturalists' Club, 1847 . .	Education Offices, Worcester. F. T. Spackman, F.G.S.	180	10*s.*	5*s.*	Transactions, annually.
Yorkshire Geological Society, 1837 . . .	Albert Gilligan, B Sc., The University, Leeds .	184	None	13*s.*	Proceedings, occasionally.
Yorkshire Naturalists' Union, 1861 . . .	The Museum, Hull. T. Sheppard, F.G.S. . .	380 and 3,050 Associates	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822 . . .	Museum, York. C. E. Elmhirst . .	300	None	2*l.* and 1*l.*	Report, annually.

Associated Societies.

Balham and District Antiquarian and Natural History Society, 1897	Miss M. Gardiner, 14a St. James' Road, Wandsworth Common, S.W	78	None	5*s.*	Report, annually; Papers, occasionally.
Barrow Naturalists' Field Club and Literary and Scientific Association, 1876	W. L. Page, 5 Cavendish Street, Barrow . .	202	None	5*s.* and 2*s* 6*d.*	Report and Proceedings, annually.
Battersea Field Club, 1894	Public Library, Lavender Hill, Battersea, S.W. Miss L. B. Morris	66	2*s.* 6*d.*	3*s.* 6*d.*	—
Bradford Natural History and Microscopical Society, 1875	Fred. Jowett, 2 Vincent Street, Bradford . .	75	1*s.*	4*s.*	—
Bradford Scientific Association, 1875 . . .	W. Newbould, 34 Burnett Avenue, Bradford .	130	None	5*s.* and 2*s.* 6*d.*	—
Catford and District Natural History Society, 1897	Thomas Coote, 25 Hawstead Road, Catford, S.E.	63	None	5*s.*	—
Dunfermline Naturalists' Society, 1902 . .	Robert Somerville, B.Sc., 31 Cameron Street, Dunfermline	150	None	5*s.*	—
Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, Coley Lodge, 21 Florence Road, Ealing, W.	122	None	10*s.* and 2*s.* 6*d.*	Report and Transactions, annually.
Grimsby and District Antiquarian and Naturalists' Society, 1896	The Museum, Grimsby. A. Bullock (Acting Sec.)	60	None	2*s.* 6*d.*	—

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
Halifax Scientific Society, 1874	J. H. Lumb, 32 Undercliffe Terrace, Halifax	180	None	2*s.* 6*d.*	—
Hastings and St. Leonards Natural History Society, 1893	W. de Muller, B.A., 14 St. Matthew's Gardens, St. Leonards-on-Sea	420	1*s.*	3*s.* 6*d.*	'Hastings and East Sussex Naturalist,' occasionally.
Hawick Archæological Society, 1856	J. J. Vernon, 81 High Street, Hawick	300	None	2*s.* 6*d.*	Transactions, annually.
Inverness Scientific Society and Field Club, 1875	Thomas Wallace, Ellerslie, Inverness	160	None	5*s.*	Transactions, occasionally.
Lancashire and Cheshire Entomological Society, 1877	Royal Institution, Liverpool. William Mansbridge	90	None	5*s.*	Report and Proceedings, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Edward J. T. Ingle, 18 Strattan Street, Leeds	100	None	5*s.* and 3*s.* 6*d.*	Proceedings, occasionally.
Lewisham Antiquarian Society, 1885	J. W. Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S.E.	73	None	5*s.*	Transactions, occasionally.
Liverpool Microscopical Society, 1868	Royal Institution, Liverpool. R. Croston	63	None	10*s.* 6*d.*	Report, annually.
Llandudno and District Field Club, 1906	L. S. Underwood, Brinkburn, Llandudno	154	None	5*s.*	Proceedings, annually.
London: London Natural History Society, 1913	J. Ross, 18 Queen's Grove Road, Chingford, N.E.	250 Members and Assoc.	2*s.* 6*d.*	5*s.* and 2*s.* 6*d.*	Report, annually; Transactions, occasionally.
London: South London Entomological and Natural History Society, 1872	Hibernia Chambers, London Bridge, S.E. Stanley Edwards, F.L.S., and H. J. Turner, F.E.S.	180	2*s.* 6*d.*	10*s.*	Proceedings, annually.
Maidstone and Mid-Kent Natural History and Philosophical Society, 1868	Maidstone Museum. A. Barton and J. W. Bridge	74	None	10*s.*	Report, occasionally.
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1793	Newcastle-upon-Tyne. Alfred Holmes	3,088	None	1*l.* 1*s.*	Report, annually; Lectures, occasionally.
Preston Scientific Society, 1893	Lecture Hall, 119A Fishergate, Preston. F. Chadderton	420	None	5*s.*	Papers, occasionally.
Scarborough Philosophical and Archæological Society, 1828	A. J. Burnley, 43 Moorland Road, Scarborough	105	None	1*l.* and 10*s.*	Report, annually.
School Nature Study Union, 1903	H. E. Turner, 1 Grosvenor Park, Camberwell, S.E.	1,670	None	2*s.* 6*d.*	'School Nature Study,' five times a year.
Southport Society of Natural Science, 1890	P. H. Christian, 9 Russell Road, Southport	222	None	5*s.*	Report, biennially.
Teign Naturalists' Field Club, 1858	John S. Amery, Druid, Ashburton, Devon	120	None	2*s.* 6*d.*	Report, annually.
Tunbridge Wells Natural History and Philosophical Society, 1884	Dr. D. Davies, 8 Lonsdale Gardens, Tunbridge Wells	129	None	10*s.* 6*d.* and 5*s.*	Report, annually.
Warrington Society, 1898	Arthur Bennet, Market Gate Chambers, Warrington	123	10*s.* 6*d*	1*l.* 11*s.* 6*d.*	—
Watford Camera Club and Photographic Society, 1902	A. Dain, 100 High Street, Watford	70	None	7*s.* 6*d.* 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, 1915.

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

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

ASHWORTH, JAMES (Manchester Geol. Min. Soc.). Notes on the Sixth and Final Report of the Explosions in Mines Committee. 'Trans. Inst. Min. Eng.' XLVIII. 604–608. 1915.

BEATTIE, Prof. J. C. The Secular Variation of the Magnetic Elements in South Africa during the period 1900–1913. 'Trans. Royal Soc. of South Africa,' IV. 181–203. 1915.

BRASHEAR, JOHN A. The Originator of Spectrum Analysis. 'Journal Royal Astr. Soc. of Canada,' VIII. 229–230. 1914.

BRIGHTON AND HOVE NATURAL HISTORY AND PHILOSOPHICAL SOCIETY. Meteorology of Brighton, 1913–1914. 'Report Brighton and Hove Nat. Hist. and Phil. Soc. 1914,' 32–33. 1914.

BRYSON, THOMAS (Min. Inst. Scotland). The Testing of Fans, with special reference to the Measurement of Pressure. 'Trans. Inst. Min. Eng.' XLVIII. 50–56. 1914.

BUFTON, WILLIAM R. Temperature and Rainfall for July, 1911. 'Trans. Woolhope Nat. Field Club, 1908–1911,' 257. 1914.

BURTON-ON-TRENT NATURAL HISTORY AND ARCHÆOLOGICAL SOCIETY. 'Meteorological Summary, 1911,' 75–77. 1914.

CAMPBELL-BAYARD, FRANCIS. Report of the Meteorological Committee, 1913. 'Trans Croydon N. H. Sci. Soc. 1913–1914,' 175–185, and Appendices, 63 pp. 1914.

CANNON, J. B. The Orbit of 136 Tauri. 'Journal Royal Astr. Soc.' IX. 151–157. 1915.

—— The Orbit of ϵ Andromedæ. 'Journal Royal Astr. Soc. of Canada,' IX. 158–164. 1915.

CARADOC AND SEVERN VALLEY FIELD CLUB. Meteorological Notes, 1913 and 1914. 'Record of Bare Facts,' No. 23, 37–53. 1914; No. 24, 23–36. 1915.

CHANT, C. A. The Meteor-Fall of Ensisheim (1492). 'Journal Royal Astr. Soc. of Canada,' VIII. 349–357. 1914.

COLLIER, HERBERT B. How I Sculptured the Moon. 'Journal Royal Astr. Soc. of Canada,' IX. 1–6. 1915.

CORNWALL ROYAL POLYTECHNIC SOCIETY. Report of the Observatory Committee. 12 pp. 'Report Royal Cornwall Poly. Soc.' 2 (N.S.). 1914.

DALTON, Dr. JOHN P. On an Experimental Modification of Van der Waals's Equation. 'Trans. Royal Soc. of South Africa,' IV. 123–136. 1914.

DENNING, W. F. Meteoric Astronomy. 'Journal Royal Astr. Soc. of Canada,' VIII. 282–286. 1914.

—— Perseids and Leonids. 'Journal Royal Astr. Soc. of Canada,' VIII. 341–344. 1914.

—— The Claims of Meteoric Astronomy. 'Journal Royal Astr. Soc of Canada,' IX. 57–60. 1915.

—— Large Meteors in June. 'Journal Royal Astr. Soc. of Canada,' IX. 61–62. 1915.

DIXON, Prof. HAROLD B. (N. Staffs. Inst. Eng.). The Nature of Explosions. 'Trans. Inst. Min. Eng.' XLIX. 214–217. 1915.

EALING SCIENTIFIC AND MICROSCOPICAL SOCIETY. Meteorological Notes for the Years 1913 and 1914. 'Report Ealing Sci. Mic. Soc.' 1913–1914, X. 1914; 1914–1915, XI. 1915.

EAST KENT NATURAL HISTORY AND SCIENTIFIC SOCIETY. Sunshine and Rainfall Tables, 1912, 1913. 'Report East Kent N. H. Sci. Soc. 1912–13,' 15. 1914.

FOX, WILSON LLOYD. Declination of the Magnetic Needle, Falmouth. 'Report Royal Cornwall Poly. Soc.' 2 (N.S.), 202. 1914.

GORDON, J. W. A 'New' Object Glass by Zeiss. 'Journal Quekett Mic. Club,' XII. 515–520. 1915.
GRAHAM, J. IVON. The Absorption of Oxygen by Coal. Part V.—The Influence of Temperature on the Rates of Absorption by different parts of the Barnsley Bed. 'Trans. Inst. Min. Eng.' XLVIII. 521–534. 1915.
—— (Midland Inst. Eng.). The Absorption of Oxygen by Coal. Part VII.—The Influence of Moisture upon the Rate of Absorption, and the Question of Bacterial Oxidation. 'Trans. Inst. Min. Eng.' XLIX. 35–43. 1915.
HARPER, W. E. Atmospheric Conditions suitable for the 72-inch Reflector. 'Journal Royal Astr. Soc. of Canada,' VIII. 172–179. 1914.
—— The Orbits of the Spectroscopic Components of 50 Draconis. 'Journal Royal Astr. Soc. of Canada,' IX. 165–167. 1915.
—— The Orbit of the Spectroscopic Binary 1149 Groombridge. 'Journal Royal Astr. Soc. of Canada,' IX. 168–169. 1915.
HAWKE, E. L. Meteorological Report for 1913 and for 1914. 'Report Hampstead Sci. Soc. 1913,' 28–30. 1914; 1914, 28–30. 1915.
HENSHAW, R. STEVENSON. Returns of Rainfall in Dorset in 1913. 'Proc. Dorset N. H. A. F. C.' XXXV. 206–219. 1914.
HOPKINSON, JOHN. The Climate of Hertfordshire, deduced from Meteorological Observations for 25 years, and Rainfall Observations for 70 years. 'Trans. Herts. N. H. S. F. C.' XV. 195–206. 1915.
—— The Weather of the Year 1913 in Hertfordshire. 'Trans. Herts N. H. S. F. C.' XV. 225–238. 1915.
HUNTER, A. F. Is there a Morning Maximum of the Aurora? 'Journal Royal Astr. Soc. of Canada,' IX. 121–125. 1915.
INNES, R. T. A. The Triple Stellar System ζ Virgo E 1757. 'Trans. Royal Soc. of South Africa,' IV. 145–146. 1914.
KAPTEYN, J. C. On the Structure of the Universe. 'Journal Royal Astr. Soc. of Canada,' VIII. 145–159. 1914.
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—— Earthquakes, Phases of the Moon, Sub-Lunar and Sub-Solar Points. 'Journal Royal Astr. Soc. of Canada,' VIII. 273–281. 1914.
—— Deformation of the Earth by the Moon. 'Journal Royal Astr. Soc. of Canada,' VIII. 375–389. 1914.
—— Magnetic Observations, 1914. 'Journal Royal Astr. Soc. of Canada,' IX. 170–172. 1915.
—— Gravity Stations, 1914. 'Journal Royal Astr. Soc. of Canada,' IX. 176–179. 1915.
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MCDIARMID, F. A. Errors in Longitude, Azimuth, and Latitude Determinations—II. 'Journal Royal Astr. Soc. of Canada,' VIII. 318–340. 1914.
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MORGAN, J. D. (N. Staff. Inst. Eng.). Coal-dust Explosions. 'Trans. Inst. Min. Eng.' XLIX. 220–229. 1915.
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MUIR, Prof. JAMES. The Constitution of Matter. 'Proc. Glasgow Royal Phil. Soc.' XLV. 76–93. 1914.
MUIR, Dr. THOMAS. Note on a Theorem of Ph. Gilbert's regarding the Differentiation of a Special Jacobian. 'Trans. Royal Soc. of S. Africa,' IV. 139–142. 1914.
—— Note on Rosanes' Functions resembling Jacobians. 'Trans. Royal Soc. of S. Africa,' IV. 157–161. 1914.
—— Properties of Pfaffians, with their Analogues in Determinants. 'Trans. Royal Soc. of S. Africa,' IV. 205–214. 1915.
—— Note on the Product of a Special N-line Determinant by its Central Minor of the $(N-4)$th Order. 'Trans. Royal Soc. of South Africa,' IV. 273–277. 1915.
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PATTERSON, J. A Meteorological Trip to the Arctic Circle. 'Journal Royal Astr. Soc. of Canada,' IX. 101–120. 1915.
PLASKETT, H. H. The Solar Rotation in 1913. 'Journal Royal Astr. Soc. of Canada,' VIII. 307–317. 1914.
PLASKETT, J. S. The 72-inch Reflecting Telescope. 'Journal Royal Astr. Soc. of Canada,' VIII. 180–187. 1914.
—— The Sidereal Universe. (Presidential Address.) 'Journal Royal Astr. Soc. of Canada,' IX. 37–56. 1915.
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RAMBAUT, A. A. Summary of the Weather during 1914, from Observations at the Radcliffe Observatory, Oxford. 'Report Ashmolean Nat. Hist. Soc. 1914,' 41. 1915.
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—— On Malet's Proof that every Equation has roots, real or imaginary, equal in number to its degree. 'Trans. Royal Soc. of South Africa,' IV. 222–229. 1915.
RUTHERFORD, JOHN. Weather and other Notes taken at Jardington during 1913. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' II. (Third Series), 144–155. 1914.
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1915



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1887. *ABBE, Professor CLEVELAND. Local Office, U.S.A. Weather Bureau, Washington, U.S.A.
1914. ‡Abbott, Hon. R. H. S. Rowan-street, Bendigo, Victoria.
1881. *Abbott, R. T. G. Whitley House, Malton.
1885. *ABERDEEN, The Marquis of, G.C.M.G., LL.D. Haddo House, Aberdeen.
1885. ‡Aberdeen, The Marchioness 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, 1906–12.) Measham Hall, Leicestershire.
1913. §Ackland, T. G., F.I.A. 5–6 Clement's Inn, Strand, W.C.
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., F.S.A. Chy-an-Mor, Gyllyngvase, Falmouth.
1877. *Acland, Theodore Dyke, M.D. 19 Bryanston-square, W.

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1915. §Adam, Sir Frank Forbes, C.I.E., LL.D. Hankelow Court, Audlem.
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1915. §Adam, M. Atkinson. The White Cottage, Knutsford.
1887. ‡Adami, J. G., M.A., M.D., F.R.S., Professor of Pathology in McGill University, Montreal, Canada.
1901. §Adams, John, M.A., B.Sc., LL.D. (Pres. L, 1912), 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.
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1913. ‡Addison, W. H. F. Medical School, The University of Pennsylvania.
1890. ‡Adeney, W. E., D.Sc., F.C.S. Burnham, Monkstown, Co. Dublin.
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1913. §Adeney, Mrs. The Prelude, Coleman's Hatch, Tunbridge Wells.
1899. *Adie, R. H., M.A., B.Sc. 136 Huntingdon-road, Cambridge.
1908. §Adkin, Robert. 4 Lingard's-road, Lewisham, S.E.
1912. ‡Afanassieff, Apollo. Physical Institute, Imperial University, Petrograd.
1908. *Agar, W. E., M.A. Natural History Department, The University, Glasgow.
1902. ‡Agnew, Samuel, M.D. Bengal-place, Lurgan.
1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
1909. *Aird, John. Canadian Bank of Commerce, Toronto, Canada.
1914. §Airey, J. W. Barooma, Vernon-street, Strathfield, Sydney.
1911. §Airey, John R., M.A., B.Sc. 73 Claremont-road, Forest Gate, E.
1895. *Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
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1910. *Alexander, W. B., B.A. Western Australian Museum, Perth, West Australia.
1891. *Alford, Charles J., F.G.S. Hotel Victoria, Rome.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1914. ‡Allan, Edward F., B.A. 37 Wattletree-road, Malvern, Victoria.
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1915. §Allen, J. E. 23 Cottenham Park-road, Wimbledon, S.W.
1907. *Allorge, M. M., L. ès Sc., F.G.S. Villa St. Germain, Louviers, France.

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1887. ‡Alward, G. L. Enfield Villa, Waltham, Grimsby, Yorkshire.
1915. §Ambler, Clement. 34 Seymour-grove, Old Trafford.
1883. §Amery, John Sparke. Druid, Ashburton, Devon.
1909. ‡Ami, H. M., M.D. Ottawa, Canada.
1884. ‡Ami, Henry, M.A., D.Sc., F.G.S. Geological Survey, Ottawa, Canada.
1914. §Anderson, Miss Adelaide M. Home Office, S.W.
1910. ‡Anderson, Alexander. Tower House, Dore, near Sheffield.
1905. *Anderson, C. L. P.O. Box 2162, Johannesburg.
1912. ‡Anderson, E. M. 43 Ladysmith-road, Edinburgh.
1908. ‡Anderson, Edgar. Glenavon, Merrion-road, Dublin.
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1914. ‡Anderson, J. R. V. School of Mines, Bendigo, Victoria.
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1908. ‡Anderson, William. Glenavon, Merrion-road, Dublin.
1911. ‡Andrade, E. N. da C. University College, Gower-street, W.C.
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1909. ‡Andrews, Alfred J. Care of Messrs. Andrews, Andrews, & Co., Winnipeg, Canada.
1895. ‡Andrews, Charles W., B.A., D.Sc., F.R.S. British Museum (Natural History), S.W.
1914. §Andrews, E. C. Geological Branch, Department of Mines, Sydney, N.S.W.
1909. ‡Andrews, G. W. 433 Main-street, Winnipeg, Canada.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1877. §Angell, John, F.C.S., F.I.C. 6 Beacons-field, Derby-road, Withington, Manchester.
1912. §Angus, Miss Mary. 354 Blackness-road, Dundee.
1886. ‡Ansell, Joseph. 27 Bennett's-hill, Birmingham.
1901. ‡Arakawa, Minozi. Japanese Consulate, 1 Broad Street-place, E.C.
1900. *Arber, E. A. Newell, M.A., F.L.S. 52 Huntingdon-road, Cambridge.
1904. *Arber, Mrs. E. A. Newell, D.Sc., F.L.S. 52 Huntingdon-road, Cambridge.
1913. ‡Archer, J. Hillside, Crowcombe, West Somerset.
1913. *Archer, R. L., M.A., Professor of Education in University College, Bangor. Plas Menai, Bangor.
1894. ‡Archibald, A. Holmer, Court-road, Tunbridge Wells.
1909. ‡Archibald, Professor E. H. Chemistry Department, University of British Columbia, Vancouver, B.C., Canada.
1909. ‡Archibald, H. Care of Messrs. Machray, Sharpe, & Dennistoun, Bank of Ottawa Chambers, Winnipeg, Canada.
1883. *Armistead, William. Hillcrest, Oaken, Wolverhampton.
1908. ‡Armstrong, E. C. R., M.R.I.A., F.R.G.S. Cyprus, Eglinton-road, Dublin.

Year of Election.

1903. *ARMSTRONG, E. FRANKLAND, D.Sc., Ph.D. Greenbank, Greenbank-road, Latchford, Warrington.
1873. *ARMSTRONG, HENRY E., Ph.D., LL.D., F.R.S. (Pres. B, 1885, 1909; Pres. L, 1902; Council, 1899–1905, 1909– .) 55 Granville-park, Lewisham, S.E.
1909. ‡Armstrong, Hon. Hugh. Parliament Buildings, Kennedy-street, Winnipeg, Canada.
1905. ‡Armstrong, John. Kamfersdam Mine, near Kimberley, Cape Colony.
1905. ‡ARNOLD, J. O., F.R.S., Professor of Metallurgy in the University of Sheffield.
1893. *ARNOLD-BEMROSE, H. H., Sc.D., F.G.S. Ash Tree House, Osmaston-road, Derby.
1915. §Arnold-Bernard, Pierre. 662 West End-avenue, New York City, U S A
1904. ‡Arunachalam, P. Ceylon Civil Service, Colombo, Ceylon.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1903. *ASHBY, THOMAS, M.A., D.Litt. The British School, Rome.
1909. ‡Ashdown, J. H. 337 Broadway, Winnipeg, Canada.
1907. ‡ASHLEY, W. J., M.A. (Pres. F, 1907), Professor of Commerce in the University of Birmingham. 3 Yateley-road, Edgbaston, Birmingham.
1915. *Ashton, Miss Margaret. 8 Kinnaird-road, Withington. Manchester.
1915. §Ashworth, Arthur. Ellerslie, Walmersley-road, Bury.
Ashworth, Henry. Turton, near Bolton.
1903. *Ashworth, J. H., D.Sc. 4 Cluny-terrace, Edinburgh.
1914. *Ashworth, Mrs. J. H. 4 Cluny-terrace, Edinburgh.
1890. ‡Ashworth, J. Reginald, D.Sc. 55 King-street South, Rochdale.
1915. §Ashworth, John. 77 King-street, Manchester.
1875. *Aspland, W. Gaskell. Care of Messrs. Boustead & Clarke, Mombasa, East Africa.
1905. ‡Assheton, Mrs. Grantchester, Cambridge.
1908. §ASTLEY, Rev. H. J. DUKINFIELD, M.A., Litt.D. East Rudham Vicarage, King's Lynn.
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., F.I.C. (Local Sec. 1891.) 44 Stuart-street, Cardiff.
1906. §AUDEN, G. A., M.A., M.D. The Education Office, Edmund-street, Birmingham.
1907. §Auden, H. A., D.Sc. 13 Broughton-drive, Grassendale, Liverpool.
1903. ‡AUSTIN, CHARLES E. 37 Cambridge-road, Southport.
1912. §Austin, Percy C., M.A., D.Sc. 101 Norwood-road, Herne Hill, S.E.
1914. ‡Avery, D., M.Sc. Collins House, Collins-street, Melbourne.
1909. ‡Axtell, S. W. Stobart Block, Winnipeg, Canada.

1914. ‡Baber, Z., Professor of Geography and Geology in the University of Chicago, U.S.A.
1883. *Bach-Gladstone, Madame Henri. 147 Rue de Grenelle, Paris.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.

Year of Election.

1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
1903. ‡Baden-Powell, Major B. 32 Prince's-gate, S.W.
1907. §Badgley, Colonel W. F., Assoc.Inst.C.E., F.R.G.S. Verecroft, Devizes.
1914. ‡Bage, Charles, M.A., M.D. 139 Collins-street, Melbourne.
1914. ‡Bage, Miss Freda. Women's College, Brisbane, Australia.
1908. *Bagnall, Richard Siddoway, F.L.S. Hope Department of Zoology, University Museum, Oxford.
1905. ‡Baikie, Robert. P.O. Box 36, Pretoria, South Africa.
1883. ‡Baildon, Dr. 42 Hoghton-street, Southport.
1883. *Bailey, Charles, M.Sc., F.L.S. Haymesgarth, Cleeve Hill S.O., Gloucestershire.
1887. *Bailey, G. H., D.Sc., Ph.D. Edenmor, Kinlochleven, Argyll, N.B
1905. *Bailey, Harry Percy. Montrose, Northdown, Margate.
1914. ‡Bailey, P. G. 4 Richmond-road, Cambridge.
1905. ‡Bailey, Right Hon. W. F., C.B. Land Commission, Dublin.
1894. *Baily, Francis Gibson, M.A. Newbury, Colinton, Midlothian.
1878. ‡Baily, Walter. 4 Rosslyn-hill, Hampstead, N.W.
1914. ‡Bainbridge, F. A., M.D., Professor of Physiology in the University of Durham, Newcastle-on-Tyne.
1905. *Baker, Sir Augustine. 56 Merrion-square, Dublin.
1913. *Baker, Bevan B., B.Sc. Frontenac, Donnington-road, Harlesden, N.W.
1910. ‡Baker, H. F., Sc.D., F.R.S. (Pres. A, 1913), Lowndean Professor of Astronomy and Geometry in the University of Cambridge. St. John's College, Cambridge.
1886. §Baker, Harry, F.I.C. Epworth House, Moughland-lane, Runcorn.
1911. §Baker, Miss Lilian, M Sc. Bryn Deiniol, Bangor.
1914. ‡Baker, R. T. Technological Museum, Sydney, N.S.W.
1915. §Baker, Miss S. M., D.Sc. Frontenac, Harlesden, N.W.
1913. ‡*Baker, Ralph Homfeld. Cambridge.*
1907. ‡Baldwin, Walter. 382 Brunshaw Top, Burnley.
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.) Whittingehame, Prestonkirk, N.B.
1894. ‡Balfour, Henry, M.A. (Pres. H, 1904.) Langley Lodge, Headington Hill, Oxford.
1905. ‡Balfour, Mrs. H. Langley Lodge, Headington Hill, Oxford.
1875. ‡Balfour, Isaac Bayley, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1894; Pres. K, 1901), Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1905. ‡Balfour, Mrs. J. Dawyck, Stobo, N.B.
1905. ‡Balfour, Lewis. 11 Norham-gardens, Oxford.
1905. ‡Balfour, Miss Vera B. Dawyck, Stobo, N.B.
1878. *Ball, Sir Charles Bent, Bart., M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1913. *Ball, Sidney, M.A. St. John's College, Oxford.
1908. ‡Ball, T. Elrington. 6 Wilton-place, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1914. ‡Balsillie, J. Greene P.M.G.'s Department, Melbourne.
1890. ‡*Bamford, Professor Harry, M.Sc.* 30 *Falkland-mansions, Glasgow.*
1909. ‡Bampfield, Mrs. E. 309 Donald-street, Winnipeg, Canada.
1912. *Bancroft, Miss Nellie, D.Sc., F.L.S. 260 Normanton-road, Derby.
1898. ‡Bannerman, W. Bruce, F.S.A. 4 The Waldrons, Croydon.
1909. ‡Baragar, Charles A. University of Manitoba, Winnipeg, Canada.

Year of Election.

1910. ‡Barber, Miss Mary. 13 Temple Fortune Court, Hendon, N.W.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1915. §Barclay, R. Noton. 35 Whitworth-street West, Manchester.
1860. *Barclay, Robert. High Leigh, Hoddesdon, 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., F.R.S. King's College, Cambridge.
1911. ‡Barger, George, M.A., D.Sc., Professor of Chemistry in the Royal Holloway College. Malahide, Englefield Green, Surrey.
1904. §Barker, B. T. P., M.A., Professor of Agricultural Biology in the University of Bristol Fenswood, Long Ashton, Bristol.
1906. *Barker, Geoffrey Palgrave. Henstead Hall, Wrentham, Suffolk.
1899. §Barker, John H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1882. *Barker, Miss J. M. Sunny Bank, Scalby, Scarborough.
1910. *Barker, Raymond Inglis Palgrave. Henstead Hall, Wrentham, Suffolk.
1913. §Barling, Dr. Gilbert. Blythe Court, Norfolk-road, Edgbaston, Birmingham.
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.
1885. *Barlow, William, F.R.S., F.G.S. The Red House, Great Stanmore.
1905. *Barnard, Miss Annie T., M.D., B.Sc. Care of W. Barnard, Esq., 3 New-court, Lincoln's Inn, W.C.
1881. *Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1904. ‡Barnes, Rev. E. W., M.A., Sc.D., F.R.S. The Temple, E.C.
1907. §Barnes, Professor H. T., Sc.D., F.R.S. McGill University, Montreal, Canada.
1915. §Barnes, Jonathan. 301 Great Clowes-street, Higher Broughton.
1909. *Barnett, Miss Edith A. Holm Leas, Worthing.
1913. §Barnett, Thomas G. The Hollies, Upper Clifton-road, Sutton Coldfield.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. (Pres. G, 1912.) Caxton-street, Anniesland, Glasgow.
1902. **Barr, Mark. Gloucester-mansions, Harrington-gardens, S.W.*
1904. ‡Barrett, Arthur. 6 Mortimer-road, Cambridge.
1872. *Barrett, Sir W. F., F.R.S., F.R.S.E., M.R.I.A. 6 De Vesci-terrace, Kingstown, Co. Dublin.
1874. *Barrington-Ward, Rev. Mark J., M.A., F.L.S., F.R.G.S. The Rectory, Duloe S.O., Cornwall.
1893. *Barrow, George, F.G.S. 202 Brecknock-road, Tufnell Park, N.
1913. ‡Barrow, Harrison. 57 Wellington-street, Edgbaston, Birmingham.
1913. ‡Barrow, Louis. 155 Middleton Hall-road, King's Norton.
1913. ‡Barrow, Walter. 13 Ampton-road, Edgbaston, Birmingham.
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.
1909. ‡Bartleet, Arthur M. 138 Hagley-road, Edgbaston, Birmingham.

Year of Election.

1909. ‡Bartlett, C. Bank of Hamilton-building, Winnipeg, Canada.
1914. ‡Barton, E. C. City Electric Light Company, Brisbane, Australia.
1893. *Barton, Edwin H., D.Sc., F.R.S.E., Professor of Experimental Physics in University College, Nottingham.
1908. ‡Barton, Rev. Walter John, M.A., F.R.G.S. Epsom College, Surrey.
1904. *Bartrum, C. O., B.Sc. 32 Willoughby-road, Hampstead, N.W.
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.
1911. *Bassett, Henry, jun., D.Sc., Ph.D. University College, Reading.
1889. ‡Bastable, Professor C. F., M.A., F.S.S. (Pres. F, 1894.) 52 Brighton-road, Rathgar, Co. Dublin.
1912. ‡Bastian, Staff-Surgeon William, R.N. Chesham Bois, Buckinghamshire.
1883. ‡Bateman, Sir A. E., K.C.M.G. Woodhouse, Wimbledon Park, S.W.
1905. *Bateman, Mrs. F. D. The Rectory, Minchinhampton.
1907. *Bateman, Harry. Lake-avenue, Govans, Md., U.S.A.
1914. ‡Bates, Mrs. Daisy M. 210 Punt-road, Prahran, Victoria.
1884. ‡Bateson, Professor William, M.A., F.R.S. (President, 1914; Pres. D, 1904.) The Manor House, Merton, Surrey.
1914. ‡Bateson, Mrs. The Manor House, Merton, Surrey.
1881. *Bather, Francis Arthur, M.A., D.Sc., F.R.S., F.G.S. British Museum (Natural History), S.W.
1915. §Batho, Cyril, Professor of Applied Mechanics in McGill University, Montreal.
1906. §Batty, Mrs. Braithwaite. Ye Gabled House, The Parks, Oxford.
1904. ‡Baugh, J. H. Agar. 92 Hatton-garden, E.C.
1909. ‡Bawlf, Nicholas Assiniboine-avenue, Winnipeg, Canada.
1913. §Bawtree, A. E., F.R.P.S. Lynton, Manor Park-road, Sutton, Surrey.
1912. *Baxter, Miss Evelyn V. Roselea, Kirkton of Largo, Fife.
1912. *Bayliss W. M., M.A., D.Sc., F.R.S. (Pres. I, 1915), Professor of General Physiology in University College, London, W.C.
1914. ‡Bayly, P. G. W. Mines Department, Melbourne.
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.
Bazley, Sir Thomas Sebastian, Bart., M.A. Kilmorie, Ilsham-drive, Torquay, Devon.
1914. §Beach, Henry, J.P. Clonesslea, Herbert-street, Dulwich Hill, Sydney.
1909. *Beadnell, H. J. Llewellyn, F.G.S. Hafod, Llandinam, Montgomeryshire.
1905. ‡Beare, Miss Margaret Pierrepont. 10 Regent-terrace, Edinburgh.
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.
1900. ‡Beaumont, Professor Roberts, M.I.Mech.E. The University, Leeds.
1885. *Beaumont, W. W., M.Inst.C.E. Outer Temple, 222 Strand, W.C.
1914. ‡Beaven, E. S. Eastney, Warminster.
1914. ‡Beaven, Miss M. J. Eastney, Warminster.
1887. *Beckett, John Hampden. Corbar Hall, Buxton, Derbyshire.
1904. §Beckit, H. O. Cheney Cottage, Headington, Oxford.

Year of Election.

1885. ‡BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector of the Zoological Society of London, Regent's Park, N.W.
1911. ‡Beddow, Fred, D.Sc., Ph.D. 2 Pier-mansions, Southsea.
1915. §Bedford, Fred, Ph.D., B Sc. Dovercourt, Heslington-lane, York.
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 SECRETARY, 1889, 1916), Professor of Chemistry in Armstrong College, Newcastle-upon-Tyne.
1901. *BEILBY, G. T., LL.D., F.R.S. (Pres. B, 1905.) 11 University-gardens, Glasgow.
1905. ‡Beilby, Hubert. 11 University-gardens, Glasgow.
1914. §Belas, Philip E., B A. University College, Cork.
1891. *Belinfante, L. L., M.Sc., Assist. Sec. G.S. Burlington House, W.
1909. ‡BELL, C. N (Local Sec. 1909.) 121 Carlton-street, Winnipeg, Canada.
1894. ‡BELL, F. JEFFREY, M.A., F.Z.S. British Museum (Natural History), S.W.
1900. *Bell, Henry Wilkinson. Beech Cottage, Rawdon, near Leeds.
1883. *Bell, John Henry. 102 Leyland-road, Southport.
1915. §Bell, S. B. 116 Cornbrook-street, Old Trafford.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1914. ‡Bell, William Reid, M.Inst.C.E. Burnie, Tasmania.
1908. *Bellamy, Frank Arthur, M.A., F.R.A.S. University Observatory, Oxford.
1904. ‡Bellars, A. E. Magdalene College, Cambridge.
1913. *Belliss, John, M.I.M.E. Darlinghurst, Carpenter-road, Edgbaston, Birmingham.
1883. *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
1901. ‡Bennett, Professor Peter. 207 Bath-street, Glasgow.
1909. *Bennett, R. B., K.C. Calgary, Alberta, Canada.
1909. ‡Benson, Miss C. C. Terralta, Port Hope, Ontario, Canada.
1903. §Benson, D. E. Queenwood, 12 Irton-road, Southport.
1901. *BENSON, Miss MARGARET J., D.Sc. Royal Holloway College, Englefield Green.
1914 ‡Benson, W. Killara, Sydney, N S W.
1887. *Benson, Mrs. W. J. 5 Wellington-court, Knightsbridge, S.W.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1904. ‡BENTLEY, B. H., M.A., Professor of Botany in the University of Sheffield.
1905. *Bentley, Wilfred. The Dene, Kirkheaton, Huddersfield.
1908. ‡*Benton, Mrs. Evelyn M. Kingswear, Hale, Altrincham, Cheshire.*
1896. *Bergin, William, M.A., Professor of Natural Philosophy in University College, Cork.
1894. §BERKELEY, The Earl of, F.R.S., F.C.S. (Council, 1909–10.) Foxcombe, Boarshill, near Abingdon.
1905. *BERNACCHI, L. C., F.R.G.S. 54 Inverness-terrace, W.
1906. *Bernays, Albert Evan. 3 Priory-road, Kew, Surrey.
1898. §Berridge, Miss C. E. 48 Stratford-road, Marloes-road, Kensington, W.
1894. *BERRIDGE, DOUGLAS, M.A., F.C.S. The College, Malvern.
1908. *Berridge, Miss Emily M. Dunton Lodge, The Knoll, Beckenham.
1914. §Berridge, Miss Isabel 7 The Knoll, Beckenham, Kent.
1908. *Berry, Arthur J. 14 Regent-street, Cambridge.
1904. §Berry, Professor R. A., F.I.C. West of Scotland Agricultural College, 6 Blythswood-square, Glasgow.
1914. §Berry, Professor R. J A , M D The University. Carlton, Melbourne.

Year of Election.

1905. ‡Bertrand, Captain Alfred. Champel, Geneva.
1862. ‡Besant, William Henry, M.A., Sc.D., F.R.S. St. John's College, Cambridge.
1913. ‡Bethune-Baker, G. T. 19 Clarendon-road, Edgbaston, Birmingham.
1880. *Bevan, Rev. James Oliver, M.A., F.S.A., F.G.S. Chillenden Rectory, Canterbury.
1884. *Beverley, Michael, M D. The Shrubbery, Scole, Norfolk.
1913. ‡Bewlay, Hubert. The Lindens, Moseley, Birmingham.
1903. ‡Bickerdike, C. F. 1 Boverney-road, Honor Oak Park, S.E.
1870. ‡Bicketon, Professor A. W. 18 Pembridge-mansions, Moscow-road, W.
1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1910. ‡*Biddlecombe, A.* 50 *Grainger-street, Newcastle-on-Tyne.*
1911. ‡Biles, Sir John H., LL.D., D.Sc. (Pres. G, 1911), Professor of Naval Architecture in the University of Glasgow. 10 University-gardens, Glasgow.
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.
1881. ‡Binnie, Sir Alexander R., M.Inst.C.E, F.G.S. (Pres. G, 1900.) 77 Ladbroke-grove, W.
1910. *Birchenough, C., M.A. 8 Severn-road, Sheffield.
1887. *Birley, H. K. Penrhyn, Irlams-o'-th'-Height, Manchester.
1915. *Birley, J. Harold. Cambridge-street, Manchester.
1913. ‡Birtwistle, G. Pembroke College, Cambridge.
1904. ‡Bishop, A. W. Edwinstowe, Chaucer-road, Cambridge.
1911. *Bishop, Major C. F., R.A. The Castle, Tynemouth, Northumberland.
1906. ‡Bishop, J. L. Yarrow Lodge, Waldegrave-road, Teddington.
1910. ‡Bisset, John. Thornhill, Insch, Aberdeenshire.
1886. *Bixby, General W. H. 735 Southern-building, Washington, U.S.A.
1914. *Black, S. G. Glenormiston, Glenormiston South, Victoria.
1909. ‡Black, W. J., Principal of Manitoba Agricultural College, Winnipeg, Canada.
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., F.R.S. Imperial College of Science and Technology, S.W.
1913. §Blackwell, Miss Elsie M., M.Sc. 16 Stanley-avenue, Birkdale, Southport.
1913. ‡Bladen, W. Wells. Stone, Staffordshire.
1909. ‡Blaikie, Leonard, M.A. Civil Service Commission, Burlington-gardens, W.
1910. ‡Blair, Sir R., M.A. London County Council, Spring-gardens, S.W.
1902. ‡Blake, Robert F., F.I.C. Queen's College, Belfast.
1914. ‡Blakemore, Mrs. D. M. Wawona, Cooper-street, Burwood, N.S.W.
1914. §Blakemore, G H Wawona, Cooper-street, Burwood, N.S.W.
1900. *Blamires, Joseph. Bradley Lodge, Huddersfield.
1905. ‡Blamires, Mrs. Bradley Lodge, Huddersfield.
1904. ‡Blanc, Dr. Gian Alberto. Istituto Fisico, Rome.
1915. §Bland, J. Arthur. Thornfield, Baxter-road, Sale.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1887. *Bles, Edward J., M.A., D.Sc. Elterholm, Madingley-road, Cambridge.

Year of Election.

1884. *Blish, William G. Niles, Michigan, U.S.A.
1913. ‡Blofield, Rev. S., B.A. Saltley College, Birmingham.
1902. ‡Blount, Bertram, F.I.C. 76 & 78 York-street, Westminster, S.W.
1888. ‡Bloxsom, Martin, B.A., M.Inst.C.E. 4 Lansdowne-road, Crumpsall Green, Manchester.
1909. ‡Blumfield, Joseph, M.D. 35 Harley-street, W.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1908. ‡Boeddicker, Otto, Ph.D. Birr Castle Observatory, Birr, Ireland.
1915. §Bohr, N. Physical Laboratory, The University, Manchester.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1911. ‡Bolland, B. G. C. Department of Agriculture, Cairo, Egypt.
1898. §Bolton, H., M.Sc., F.R.S.E. The Museum, Queen's-road, Bristol.
1894. §Bolton, John, F.R.G.S. 22 Hawes-road, Bromley, Kent.
1898. *Bonar, James, M.A., LL.D. (Pres. F, 1898; Council, 1899–1905.) The Mint, Ottawa, Canada.
1909. ‡Bonar, Thomson, M.D. 114 Via Babuino, Piazza di Spagna, Rome.
1912. *Bond, C. I., F.R.C.S. Springfield-road, Leicester.
1914. ‡Bond, Mrs. C. I. Springfield-road, Leicester.
1909. ‡Bond, J. H. R., M.B. 167 Donald-street, Winnipeg, Canada.
1908. ‡Bone, Professor W. A., D.Sc., F.R.S. (Pres. B, 1915; Council, 1915– .) Imperial College of Science and Technology, S.W.
1913. ‡*Bonnar, W., LL.B., Ph D. Hotel Cecil, Strand, W.C.*
1871. *Bonney, Rev. Thomas George, Sc.D., LL.D., F.R.S., F.S.A., F.G.S. (President, 1910; Secretary, 1881–85; Pres. C, 1886.) 9 Scroope-terrace, Cambridge.
1911. ‡Bonny, W. Naval Store Office, The Dockyard, Portsmouth.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Sir Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *Booth, Right Hon. Charles, Sc.D., F.R.S., F.S.S. 28 Campden House Court, Kensington, W.
1883. ‡Booth, James. Hazelhurst, Turton.
1910. §Booth, John, M.C.E., B.Sc. The Gables, Berkeley-street, Hawthorn, Victoria, Australia.
1883. ‡Boothroyd, Benjamin. Weston-super-Mare.
1901. *Boothroyd, Herbert E., M.A., B.Sc. Sidney Sussex College, Cambridge.*
1912. ‡Borgmann, Professor J. J., D.Ph., LL.D. Physical Institute, The University, Petrograd.
1882. §Borns, Henry, Ph.D. 5 Sutton Court-road, Chiswick, W.
1901. ‡Borradaile, L. A., M.A. Selwyn College, Cambridge.
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., M.A., Professor of Botany in King's College, Strand, W.C.
1909. ‡Boulenger, C. L., M.A., D.Sc. The University, Birmingham.
1905. ‡Boulenger, G. A., LL.D., F.R.S. (Pres. D, 1905.) 8 Courtfield-road, S.W.

Year of Election.

1905. ‡Boulenger, Mrs. 8 Courtfield-road, S.W.
1903. §Boulton, W. S., D.Sc., F.G.S., Professor of Geology in the University of Birmingham.
1911. ‡Bourdillon, R. Balliol College, Oxford.
1883. ‡Bourne. Sir A. G., K C I E, D Sc., F R.S., F.L S. Middlepark, Paignton, South Devon
1914. §Bourne, Lady. Middlepark, Paignton, South Devon.
1893. *Bourne, G. C., M.A., D.Sc., F.R.S., F.L.S. (Pres. D, 1910; Council, 1903-09; Local Sec. 1894), Linacre Professor of Comparative Anatomy in the University of Oxford. Savile House, Mansfield-road, Oxford.
1904. *Bousfield, E. G. P. St. Swithin's, Hendon, N.W.
1913. ‡Bowater, Sir W. H. Elm House, Arthur-road, Edgbaston, Birmingham.
1913. ‡Bowater, William. 20 Russell-road, Moseley, Birmingham.
1881. *Bower, F. O., D.Sc., F.R.S., F.R.S.E., F.L.S. (Pres. K, 1898, 1914; Council, 1900-06), Regius Professor of Botany in the University of Glasgow.
1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Whitehill, Wrotham, Kent.
1908. §Bowles, E. Augustus, M.A., F.L.S. Myddelton House, Waltham Cross, Herts.
1898. ‡Bowley, A. L., M.A. (Pres. F, 1906; Council, 1906-11.) Northcourt-avenue, Reading.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1899. *Bowman, Herbert Lister, M.A., D.Sc., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
1899. *Bowman, John Herbert. Greenham Common, Newbury.
1887. §Box, Alfred Marshall. 14 Magrath avenue, Cambridge.
1901. ‡Boyd, David T. Rhinsdale, Ballieston, Lanark.
1915. *Boyd, H. de H. Care of Southern Cotton Oil Company, Trafford Park, Manchester.
1892. ‡Boys, Charles Vernon, F.R.S. (Pres. A, 1903; Council, 1893-99, 1905-08.) 66 Victoria-street, S.W.
1872. *Brabrook, Sir Edward, C.B., F.S.A. (Pres. H, 1898; Pres. F, 1903; Council, 1903-10, 1911- .) Langham House, Wallington, Surrey.
1894. *Braby, Ivon. Helena, Alan-road, Wimbledon, S.W.
1915. §Bradley, F. E., M.A. Bank of England-chambers, Manchester.
1893. ‡Bradley, F. L. Ingleside, Malvern Wells.
1904. *Bradley, Gustav. Council Offices, Goole.
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. Park Hurst, Endcliffe, Sheffield.
1911. §Bragg, W. H., M.A., F.R.S. (Council, 1913-), Professor of Physics in the University of Leeds.
1905. §Brakhan, A. 6 Montague-mansions, Portman-square, W.
1906. ‡Branfield, Wilfrid. 4 Victoria-villas, Upperthorpe, Sheffield.
1885. *Bratby, William, J.P. Alton Lodge, Lancaster Park, Harrogate.
1905. ‡Brausewetter, Miss. Roedean School, near Brighton.
1909. §Bremner, Alexander. 38 New Broad-street, E.C.
1905. ‡Bremner, R. S. Westminster-chambers, Dale-street, Liverpool.
1905. ‡Bremner, Stanley. Westminster-chambers, Dale-street, Liverpool.

Year of Election.

1913. *Brenchley, Miss Winifred E., D.Sc., F.L.S. Rothamsted Experimental Station, Harpenden, Herts.
1902. *Brereton, Cloudesley. 7 Lyndhurst-road, Hampstead, N.W.
1909. *Breton, Miss Adela C. Care of Lloyd's Bank, Bath.
1905. §Brewis, E. 27 Winchelsea-road, Tottenham, N.
1908. ‡Brickwood, Sir John. Branksmere, Southsea.
1907. *Bridge, Henry Hamilton. Fairfield House, Droxford, Hants.
1912. ‡Bridgman, F. J., F.L.S. Zoological Department, University College, W.C.
1913. ‡Brierley, Leonard H. 11 Ampton-road, Edgbaston, Birmingham.
1913. §Briggs, W. Friars Croft, Park-drive, Hale, Cheshire.
1904. *Briggs, William, M.A., LL.D., F.R.A.S. Burlington House, Cambridge.
1909. *Briggs, Mrs. William. Owlbrigg, Cambridge.
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, 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. Birstall, Leicester.
1915. §Brocklehurst, F. 33 King-street, Manchester.
1901. ‡Brodie, T. G., M.D., F.R.S., Professor of Physiology in the University of Toronto. The University, Toronto, Canada.
1883. *Brodie-Hall, Miss W. L. Havenwood, Peaslake, Gomshall, Surrey.
1903. ‡Brodrick, Harold, M.A., F.G.S. (Local Sec. 1903.) 7 Aughton-road, Birkdale, Southport.
1913. ‡Brodrick, Mrs. Harold. 7 Aughton-road, Birkdale, Southport.
1904. ‡Bromwich, T. J. I'A., M.A., F.R.S. 1 Selwyn-gardens, Cambridge.
1906. ‡Brook, Stanley. 18 St. George's-place, York.
1911. §Brooke, Colonel Charles K., F.R.G.S. Army and Navy Club, Pall Mall, S.W.
1915. §Brooks, Colin. 7 Cedar-street, Southport.
1906. *Brooks, F. T. 31 Tenison-avenue, Cambridge.
1883. *Brough, Mrs. Charles S. 4 Spencer-road, Southsea.
1886. ‡Brough, Joseph, LL.D., Professor of Logic and Philosophy in University College, Aberystwyth.
1913. §Brown, Professor A. J., M.Sc., F.R.S. West Heath House, Northfield, Birmingham.
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.
1914. §Brown, F. G., B.A., B Sc. Naval College, North Geelong, Victoria.
1903. ‡Brown, F. W. 6 Rawlinson-road, Southport.
1914. ‡Brown, Rev. George, D.D. Kinawanua, Gordon, N.S.W.
1870. §Brown, Horace T., LL.D., F.R.S., F.G.S. (Pres. B, 1899; Council, 1904–11.) 52 Nevern-square, S.W.

Year of Election.

1881. *Brown, John, M.D. Liesbreek-road, Mowbray, Cape of Good Hope.
1895. *Brown, John Charles. 39 Burlington-road, Sherwood, Nottingham.
1882. *Brown, Mrs. Mary. Liesbreek-road. Mowbray, Cape of Good Hope.
1901. ‡Brown, Professor R. N. Rudmose, D.Sc. The University, Sheffield.
1908. §Brown, Sidney G. 52 Kensington Park-road, W.
1905. §Brown, Mrs. Sidney G. 52 Kensington Park-road, W.
1910. *Brown, Sidney J. R. 52 Kensington Park-road, W.
1912. ‡Brown, T. Graham. The University, Liverpool.
1884. ‡Brown, W. G. University of Missouri, Columbia, Missouri, U.S.A.
1908. ‡Brown, William, B.Sc. 48 Dartmouth-square, Dublin.
1912. ‡Brown, Dr. William. Thornfield, Horley, Surrey.
1906. ‡Browne, Charles E., B.Sc. Christ's Hospital, West Horsham.
1900. *Browne, Frank Balfour, M.A., F.R.S.E., F.Z.S. 26 Barton-road, Cambridge.
1908. ‡Browne, Rev. Henry, M.A., Professor of Greek in University College, Dublin.
1895. **Browne, H. T. Doughty.* 6 *Kensington House, Kensington-court, W.*
1879. ‡Browne, Sir J. Crichton, M.D., LL.D., F.R.S., F.R.S.E. 41 Hans-place, S.W.
1905. *Browne, James Stark, F.R.A.S. Hanmer House, Mill Hill Park, W.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1912. §Browning, T. B., M.A. 18 Bury-street, Bloomsbury, W.C
1905. §Bruce, Surgeon-General Sir David, A.M.S., C.B., F.R.S. (Pres. I, 1905.) Royal Army Medical College, Grosvenor-road, S.W.
1905. ‡Bruce, Lady. 3p Artillery-mansions, Victoria-street, S.W.
1893. ‡Bruce, William S., LL.D., F.R.S.E. Scottish Oceanographical Laboratory, Surgeons' Hall, Edinburgh.
1900. *Brumm, Charles. Edendale, Whalley-road, Whalley Range, Manchester.
1896. *Brunner, Right Hon. Sir J. T., Bart. Silverlands, Chertsey.
1868. ‡Brunton, Sir T. Lauder, Bart., M.D., Sc.D., F.R.S. (Council, 1908–12.) 1 De Walden-court, New Cavendish-street, 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.
1909. ‡Bryce, Thomas H., M.D., Professor of Anatomy in the University of Glasgow. 2 The College, 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, Hon. Sir John. Clareinch, Claremont, Cape Town.
1909. ‡Buchanan, W. W. P.O. Box 1658, Winnipeg, Canada.
1914. ‡Buck, E. J. Menzies' Hotel, Melbourne.
1913. ‡Buckland, H. T. 21 Yateley-road, Edgbaston, Birmingham.
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. Dymboro, Midsomer Norton, Bath.
1913. *Bulleid, C. H. University College, Nottingham.
1913. *Buller, A. H. Reginald, Professor of Botany in the University of Manitoba, Winnipeg.
1909. ‡Bulyea, The Hon. G. H. V. Edmonton, Alberta, Canada.

Year of Election.

1914. ‡Bundey, Miss E. M. Molesworth-street, North Adelaide, South Australia.
1905. ‡Burbury, Mrs. A. A. 15 Melbury-road, W.
1905. ‡Burbury, Miss A. D. 15 Melbury-road, W.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1905. ‡Burdon, E. R., M.A. Ikenhilde, Royston, Herts.
1913. ‡Burfield, Stanley Thomas. Zoology Department, The University, Liverpool.
1913. *Burgess, J. Howard. Shide, Newport, Isle of Wight.
1894. ‡Burke, John B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Colonel Jeffrey H. 342 Sherbrooke-street West, Montreal, Canada.
1915. §Burlin, Adolph L., Ph.D. 231 Brunswick-street, Chorlton-on-Medlock, Manchester.
1899. ‡Burls, H. T., F.G.S. 2 Verulam-buildings, Gray's Inn, W.C.
1904. ‡Burn, R. H. 21 Stanley-crescent, Notting-hill, W.
1909. ‡Burns, F. D. 203 Morley-avenue, Winnipeg, Canada.
1914. *Burns, Colonel James. Gowan Brae, Parramatta, N.S.W.
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.
1909. ‡Burrows, Theodore Arthur. 187 Kennedy-street, Winnipeg, Canada.
1910. ‡Burt, Cyril. L.C.C. Education Offices, Victoria Embankment, W.C.
1894. ‡Burton, C. V. Boar's Hill, Oxford.
1909. ‡Burton, E. F. 129 Howland-avenue, Toronto, Canada.
1911. ‡Burton, J. H. Agriculture Office, Weston-super-Mare.
1892. ‡Burton-Brown, Colonel A., F.G.S. Royal Societies Club, St. James's-street, S.W.
1904. ‡Burtt, Arthur H., D.Sc. 4 South View, Holgate, York.
1906. ‡Burtt, Philip. Swarthmore, St. George's-place, York.
1909. ‡Burwash, E. M., M.A. New Westminster, British Columbia, Canada.
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.
1908. *Bushell, W. F. Rossall School, Fleetwood.
1910. ‡Butcher, Miss. 25 Earl's Court-square, S.W.
1884 *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1913. *Butler, W. Waters. Southfield, Norfolk-road, Edgbaston, Birmingham.
1915. *Butterworth, Charles F. Waterloo, Poynton, Cheshire.
1884. Butterworth, W. Carisbrooke, Rhin-road, Colwyn Bay, North Wales.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1899. ‡Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.

1913. §Cadbury, Edward. Westholme, Selly Oak, Birmingham.
1913. ‡Cadbury, W. A. Wast Hills, King's Norton.
1892. ‡Cadell, H. M., B.Sc., F.R.S.E. Grange, Linlithgow.
1913. ‡Cadman, John, C.M.G., D.Sc., Professor of Mining in the University of Birmingham. 61 Wellington-road, Edgbaston, Birmingham.
1913. ‡Cadman, Lieutenant W. H., B.Sc. Bryncliffe Lodge, Little Orme, Llandudno.

Year of Election.

1913. ‡Cahill, J. R. 49 Hanover Gate-mansions, Regent's Park, N.W.
1912. §Caine, Nathaniel. Spital, Cheshire.
1861. *Caird, Sir James Key, Bart., LL.D. 8 Magdalen Yard-road, Dundee.
1901. ‡Caldwell, Hugh. Blackwood, Newport, Monmouthshire.
1907. ‡Caldwell, K. S. St. Bartholomew's Hospital, E.C.
1897. ‡Callendar, Hugh L., M.A., LL.D., F.R.S. (Pres. A, 1912; Council, 1900-06), Professor of Physics in the Imperial College of Science and Technology, S.W.
1911. ‡Calman, W. T., D.Sc. British Museum (Natural History), Cromwell-road, S.W.
1914. ‡Cambage, R. H., F.L.S. Department of Mines, Sydney, N.S.W.
1911. ‡Cameron, Alexander T. Physiological Department, University of Manitoba, Winnipeg.
1857. ‡Cameron, Sir Charles A., C.B., M.D. 51 Pembroke-road, Dublin.
1909. ‡Cameron, D. C. 65 Roslyn-road, Winnipeg, Canada.
1896. §Cameron, Irving H., LL.D., Professor of Surgery in the University of Toronto. 307 Sherbourne-street, Toronto, Canada.
1909. ‡Cameron, Hon. Mr. Justice J. D. Judges' Chambers, Winnipeg, Canada.
1901. §Campbell, Archibald. Park Lodge, Albert-drive, Pollokshields, Glasgow.
1897. ‡Campbell, Colonel J. C. L. Achalader, Blairgowrie, N.B.
1909. *Campbell, R. J. Holdenhurst, Hendon-avenue, Church End, Finchley, N.
1909. ‡Campbell, Mrs. R. J. Holdenhurst, Hendon-avenue, Church End, Finchley, N.
1902. ‡Campbell, Robert. 21 Great Victoria-street, Belfast.
1912. ‡Campbell, Dr. Robert. Geological Department, The University, Edinburgh.
1890. ‡Cannan, Professor Edwin, M.A., LL.D., F.S.S. (Pres. F, 1902.) 11 Chadlington-road, Oxford.
1905. ‡Cannan, Gilbert. King's College, Cambridge.
1897. §Cannon, Herbert. Alconbury, Bexley Heath, Kent.
1904. ‡Capell, Rev. G. M. Passenham Rectory, Stony Stratford.
1911. ‡Capon, R. S. 49A Rodney-street, Liverpool.
1905. *Caporn, Dr. A. W. Muizenberg, South Africa.
1894. ‡Capper, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1887. ‡Capstick, J. W. Trinity College, Cambridge.
1896. **Carden, H. Vandeleur. Fir Lodge, Broomfield, Chelmsford.*
1913. ‡Carlier, E. Wace, M.Sc., M.D., F.R.S.E., Professor of Physiology in the University of Birmingham. The University, Edmund-street, Birmingham.
1914. ‡Carne, J. E. Mines Department, Sydney, N.S.W.
1913. §Carpenter, Charles. 157 Victoria-street, S.W.
1913. *Carpenter, G. D. H., M.B. 19 Bardwell-road, Oxford.
1902. ‡Carpenter, G. H., B.Sc., Professor of Zoology in the Royal College of Science, Dublin.
1906. *Carpenter, H. C. H. 30 Murray-road, Wimbledon.
1905. §Carpmael, Edward, F.R.A.S., M.Inst.C.E. The Ivies, 118 St. Julian's Farm-road, West Norwood, S.E.
1912. *Carr, H. Wildon, D.Litt. 10 More's Garden, Cheyne-walk, S.W.
1910. ‡Carr, Henry F. Broadparks, Pinhoe, near Exeter.
1893. ‡Carr, J. Wesley, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1906. *Carr, Richard E. Sylvan Mount, Sylvan-road, Upper Norwood, S.E.

Year of Election.

1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1911. ‡Carruthers, R. G., F.G.S. Geological Survey Office, 33 George-square, Edinburgh.
1867. ‡Carruthers, William, F.R.S., F.L.S., F.G.S. (Pres. D, 1886.) 44 Central-hill, 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.
1914. §Carson, Rev James. The Manse, Cowper, N S W.
1900. *Carter, W. Lower, M.A., F.G.S. Bolbec, Grange Road, Watford.
1896. ‡Cartwright, Miss Edith G. 21 York Street-chambers, Bryanston-square, W.
1878. *Cartwright, Ernest H., M.A., M.D. Myskyns, Ticehurst, Sussex.
1870. §Cartwright, Joshua, M.Inst C.E., F.S.I. 21 Parsons-lane, Bury, Lancashire.
1862. ‡Carulla, F. J R 84 Rosehill-street, Derby
1894. ‡Carus, Dr. Paul. La Salle, Illinois, U.S.A.
1913. §Carus-Wilson, Cecil, F R S E, F G.S. Altmore, Waldegrave-park, Strawberry Hill, Twickenham.
1901. ‡Carver, Thomas A. B., D.Sc., Assoc.M.Inst.C.E. 9 Springfield-road, Dalmarnock, Glasgow.
1899. *Case, J. Monckton. Department of Lands (Water Branch), Victoria, British Columbia.
1897. *Case, Willard E Auburn, New York, U.S.A.
1908. *Cave, Charles J. P, M.A. Ditcham Park, Petersfield.
1910. ‡Chadburn, A. W. Brincliffe Rise, Sheffield.
1905. *Challenor, Bromley, M.A. The Firs, Abingdon.
1905. *Challenor, Miss E. M. The Firs, Abingdon.
1910. §Chalmers, Stephen D. 25 Cornwall-road, Stroud Green, N.
1913. ‡Chalmers, Mrs. S. D. 25 Cornwall-road, Stroud Green, N.
1913. ‡Chamberlain, Neville. Westbourne, Edgbaston, Birmingham.
1914. §Chamberlin, Dr. R. T. Geological Department, University of Chicago, U S.A.
1913. †Chambers, Miss Beatrice Anne. Glyn-y-mêl, Fishguard.
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.
1888. ‡Chandler, S. Whitty, B.A. St. George's, Cecil-road, Boscombe.
1907. *Chapman, Alfred Chaston, F.I.C. 8 Duke-street, Aldgate, E.C.
1902. *Chapman, D. L., M.A., F.R.S. Jesus College, Oxford.
1914. §Chapman, H. G., M.D. Department of Physiology, The University, Sydney, N.S.W.
1910. ‡Chapman, J. E. Kinross.
1899. §Chapman, Professor Sydney John, M.A., M.Com. (Pres. F, 1909.) Burnage Lodge, Levenshulme, Manchester.
1912. *Chapman, Sydney, D.Sc., B.A., F.R.A.S. Trinity College, Cambridge.
1910. ‡*Chappell, Cyril.* 73 *Neill-road, Sheffield.*
1905. ‡Chassigneux, E. 12 Tavistock-road, Westbourne-park, W.
1904. *Chattaway, F. D., M.A., D.Sc., Ph.D., F.R.S. 151 Woodstock-road, Oxford.
1886. *Chattock, A. P., D.Sc. Heathfield Cottage, Crowcombe, Somerset.

Year of Election.

1904. *Chaundy, Theodore William, M.A. Christ Church, Oxford.
1913. ‡Cheesman, Miss Gertrude Mary. The Crescent, Selby.
1900. *Cheesman, W. Norwood, J.P., F.L.S. The Crescent, Selby.
1874. *Chermside, Lieut.-General Sir Herbert, R.E., G.C.M.G., C.B. Newstead Abbey, Nottingham.
1908. ‡Cherry, Right Hon. Lord Justice. 92 St. Stephen's Green, Dublin.
1910. ‡Chesney, Miss Lilian M., M.B. 381 Glossop-road, Sheffield.
1879. *Chesterman, W. Belmayne, Sheffield.
1911. *Chick, Miss H., D.Sc. Chestergate, Park-hill, Ealing, W.
1908. ‡Chill, Edwin, M.D. Westleigh, Mattock-road, Ealing, W.
1883. ‡Chinery, Edward F., J.P. Lymington.
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.
1904. §Chivers, John, J.P. Wychfield, Cambridge.
1882. ‡Chorley, George. Midhurst, Sussex.
1909. ‡Chow, H. H., M.D. 263 Broadway, Winnipeg, Canada.
1893. *Chree, Charles, Sc.D., F.R.S. Kew Observatory, Richmond, Surrey.
1913. §Christie, Dr. M. G. Post Office House, Leeds.
1900. *Christie, R. J. Duke-street, Toronto, Canada.
1875. *Christopher, George, F.C.S. Thorncroft, Chislehurst.
1903. ‡Clapham, J. H., M.A. King's College, Cambridge.
1901. §Clark, Archibald B., M.A., Professor of Political Economy in the University of Manitoba, Winnipeg, Canada.
1905. *Clark, Cumberland, F.R.G.S. 22 Kensington Park-gardens, W.
1907. *Clark, Mrs. Cumberland. 22 Kensington Park-gardens, W.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
1902. ‡Clark, G. M. South African Museum, Cape Town.
1881. *Clark, J. Edmund, B.A., B.Sc. Asgarth, Riddlesdown-road. Purley, Surrey.
1909. ‡Clark, J. M., M.A., K.C. The Kent Building, 156 Yonge-street, Toronto, Canada.
1908. ‡Clark, James, B.Sc., Ph.D. Newtown School, Waterford, Ireland.
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. Chartfield Cottage, Brasted Chart, Kent.
1889. *Clayden, A. W., M.A., F.G.S. 5 The Crescent, Mount Radford, Exeter
1909. §Cleeves, Frederick, F.Z.S. 120 Fenchurch-street, E.C.
1909. ‡Cleeves, W. B. Public Works Department, Government-buildings, Pretoria.
1915. §Clegg, John Gray. 22 St. John-street, Manchester.
1861. ‡Cleland, John, M.D., D.Sc., F.R.S. Drumclog, Crewkerne, Somerset.
1905. §Cleland, Mrs. Drumclog, Crewkerne, Somerset.
1905. §Cleland, Lieutenant J. R. Drumclog, Crewkerne, Somerset.
1902. ‡Clements, Olaf P. Tana, St. Bernard's-road, Olton, Warwick.
1904. §Clerk, Dugald, D.Sc., F.R.S., M.Inst.C.E. (Pres. G, 1908; Council, 1912– .) 57 and 58 Lincoln's Inn Fields, W.C.
1909. ‡Cleve, Miss E. K. P. 74 Kensington Gardens-square, W.
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S. 3 Bardwell-road, Banbury-road, Oxford.

Year of Election.

1906. §Close, Colonel C. F., R.E., C.M.G., F.R.G.S. (Pres. E, 1911; Council, 1908–12.) Ordnance Survey Office, Southampton.
1914. ‡Close, J. Campbell. 217 Clarence-street, Sydney, N.S.W.
1883. *Clowes, Professor Frank, D.Sc., F.C.S. (Local Sec. 1893.) The Grange, College-road, Dulwich, S.E.
1914. ‡Clowes, Mrs. The Grange, College-road, Dulwich, S.E.
1912. §Clubb, Joseph A., D.Sc. Free Public Museum, Liverpool.
1891. *Coates, Henry, F.R.S.E. Corarder, Perth.
1911. §Cobbold, E. S., F.G.S. Church Stretton, Shropshire.
1908. *Cochrane, Miss Constance. The Downs, St. Neots.
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.
1913. ‡Codd, J. Alfred. 7 Tettenhall-road, Wolverhampton.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1898. ‡Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *Coffin, Walter Harris, F.C.S. National Liberal Club, S.W.
1896. *Coghill, Percy de G. Sunnyside House, Prince's Park, Liverpool.
1914. ‡Coghill, Mrs. Una. Monomeath-avenue, Canterbury, Victoria.
1887. ‡Cohen, Professor J. B. The University, Leeds.
1901. *Cohen, R. Waley, B.A. 11 Sussex-square, W.
1906. *Coker, Ernest George, M.A., D.Sc., F.R.S.E. (Pres. G, 1914), Professor of Civil and Mechanical Engineering, University College, Gower-street, W.C.
1914. ‡Coker, Mrs. 3 Farnley-road, Chingford, Essex.
1895. *Colby, William Henry. 80 Coldharbour-road, Redland, Bristol.
1913. §Cole, Professor F. J. University College, Reading.
1893. §Cole, Grenville A. J., F.G.S. (Pres. C, 1915), Professor of Geology in the Royal College of Science, Dublin.
1903. ‡Cole, Otto B. 551 Boylston-street, Boston, U.S.A.
1910. §Cole, Thomas Skelton. Westbury, Endcliffe-crescent, Sheffield.
1897. §Coleman, Professor A. P., M.A., Ph.D., F.R.S. (Pres. C, 1910.) 476 Huron-street, Toronto, Canada.
1899. ‡Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1912. ‡Collett, J. M., J.P. Kimsbury House, Gloucester.
1887. ‡Collie, J. Norman, Ph.D., F.R.S., Professor of Organic Chemistry in the University of London. 16 Campden-grove, W.
1913. ‡Collinge, Walter E., M.Sc. The Gatty Marine Laboratory, The University, St. Andrews, N.B.
1861. *Collingwood, J. Frederick, F.G.S. 8 Oakley-road, Canonbury, N.
1876. ‡Collins, J. H., F.G.S. Crinnis House, Par Station, Cornwall.
1910. *Collins, S. Hoare. 9 Cavendish-place, Newcastle-on-Tyne.
1902. ‡Collins, T. R. Belfast Royal Academy, Belfast.
1914. ‡Collum, Mrs. Anna Maria. 18 Northbrook-road, Leeson Park, Dublin.
1892. ‡Colman, Dr. Harold G. 1 Arundel-street, Strand, W.C.
1910. *Colver, Robert, jun. Graham-road, Ranmoor, Sheffield.
1905. *Combs, Rev. Cyril W., M.A. Elverton, Castle-road, Newport, Isle of Wight.
1910. *Compton, Robert Harold, B.A. Gonville and Caius College, Cambridge.
1912. §Conner, Dr. William. The Priory, Waterlooville, Hants.
1902. ‡*Conway, A. W.* 100 *Leinster-road, Rathmines, Dublin.*

Year of Election.

1903. ‡Conway, R. Seymour, Litt.D., Professor of Latin in Owens College, Manchester.
1898. ‡Cook, Ernest H., D.Sc. 27 Berkeley-square, Clifton, Bristol.
1913. §Cook, Gilbert, M.Sc., Assoc.M.Inst.C.E. Engineering Department, The University, Manchester.
1876. *Cooke, Conrad W. The Pines, Langland-gardens, Hampstead, N.W.
1911. ‡Cooke, J. H. 101 Victoria-road North, Southsea.
1914. ‡Cooke, William Ternant, D.Sc. Fourth-avenue, East Adelaide, South Australia.
1915. §Cookson, A. Ellis. 14 Hargreaves-buildings, Liverpool.
1888. ‡Cooley, George Parkin. Constitutional Club, Nottingham.
1899. **Coomaraswamy, A. K., D.Sc., F.L.S., F.G.S. Broad Campden, Gloucestershire.*
1903. ‡Cooper, Miss A. J. 22 St. John-street, Oxford.
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1911. §Cooper, W. E. Henwick Lodge, Worcester.
1912. §Cooper, W. F. The Laboratory, Rickmansworth-road, Watford.
1907. ‡Cooper, William. Education Offices, Becket-street, Derby.
1904. *Copeman, S. Monckton, M.D., F.R.S. Local Government Board, Whitehall, S.W.
1909. §Copland, Mrs. A. J. Gleniffer, 50 Woodberry Down, N.
1904. *Copland, Miss Louisa. 10 Wynnstay-gardens, Kensington, W.
1909. ‡Corbett, W. A. 207 Bank of Nova Scotia-building, Winnipeg, Canada.
1894. §Corcoran, Miss Jessie R. Rotherfield Cottage, Bexhill-on-Sea.
1915. §Corker, James S. Care of Macintosh & Co., Ltd., Cambridge-street, Manchester.
1901. *Cormack, J. D., D.Sc., Professor of Civil Engineering and Mechanics in the University of Glasgow.
1893. *Corner, Samuel, B.A., B.Sc. Abbotsford House, Waverley-street, Nottingham.
1889. ‡Cornish, Vaughan, D.Sc., F.R.G.S. Woodville, Camberley.
1884. *Cornwallis, F. S. W., F.L.S. Linton Park, Maidstone.
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.
1909. *Cossar, G. C., M.A., F.G.S. Southview, Murrayfield, Edinburgh.
1910. ‡Cossar, James. 28 Coltbridge-terrace, Murrayfield, Midlothian.
1911. ‡Cossey, Miss, M.A. High School for Girls, Kent-road, Southsea.
1908. *Costello, John Francis, B.A. The Rectory, Ballymackey, Nenagh, Ireland.
1874. *Cotterill, J. H., M.A., F.R.S. Hillcrest, Parkstone, Dorset.
1908. ‡Cotton, Alderman W. F., D.L., J.P., M.P. Hollywood, Co. Dublin.
1915. §Courcy-Meade, T. de. Westella, Buxton.
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.
1911. ‡Couzens, Sir G. E., K.L.H. Glenthorne, Kingston-crescent, Portsmouth.
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.
1915. §Coward, H. F. 216 Plymouth-grove, Manchester.
1900. ‡Cowburn, Henry. Dingle Head, Leigh, Lancashire.
1914. ‡Cowburn, Mrs. Dingle Head, Leigh, Lancashire.

Year of Election.

1895. *Cowell, Philip H., M.A., D.Sc., F.R.S. 62 Shooters Hill-road, Blackheath, S.E.
1899. ‡Cowper-Coles, Sherard. 1 and 2 Old Pye-street, Westminster, S.W.
1913. ‡Cox, A. Hubert. King's College, Strand, W.C.
1909. ‡Cox, F. J. C. Anderson-avenue, Winnipeg, Canada.
1905. ‡Cox, W. H. Royal Observatory, Cape Town.
1912. ‡Craig, D. D., M.A., B.Sc., M.B. The University, St. Andrews, N.B.
1911. §Craig, J. I. Homelands, Park-avenue, Worthing.
1908. ‡Craig, James, M.D. 18 Merrion-square North, Dublin.
1884. §Craigie, Major P. G., C.B., F.S.S. (Pres. F, 1900; Council, 1908–15.) Bronté House, Lympstone, Devon.
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. Imperial Cancer Research Fund, Queen-square, Bloomsbury, W.C.
1906. ‡Cramp, William, D.Sc. 33 Brazennose-street, Manchester.
1905. *Cranswick, W. F. P.O. Box 65, Bulawayo, Rhodesia.
1906. ‡Craven, Henry. (Local Sec. 1906.) Greenbank, West Lawn, Sunderland.
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.
1910. *Crawford, O. G. S. The Grove, East Woodhay, Newbury.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Colinton-road, Edinburgh.
1905. ‡Crawford, W. C., jun. 1 Lockharton-gardens, Colinton-road, Edinburgh.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.
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. Whitstead, Barton-road, Cambridge.
1887. *Crewdson, Theodore. Spurs, Styall, Handforth, Manchester.
1911. ‡Crick, George C., F.G.S. British Museum (Natural History), S.W.
1904. ‡Crilly, David. 7 Well-street, Paisley.
1880. *Crisp, Sir Frank, Bart., 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. Quedley, Shottermill.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. *Croke, John O'Byrne, M.A. Clouncagh, Ballingarry-Lacy, Co. Limerick.
1913. §Crombie, J. E. Parkhill House, Dyce, Aberdeenshire.
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.
1914. ‡Cronin, J. Botanic Gardens, South Yarra, Australia.
1887. ‡Crook, Henry T., M.Inst.C.E. Lancaster-avenue, Manchester.
1898. §Crooke, William, B.A. (Pres. H, 1910; Council, 1910– .) Langton House, Charlton Kings, Cheltenham.
1865. §Crookes, Sir William, O.M., D.Sc., F.R.S., V.P.C.S. (President, 1898; Pres. B, 1886; Council, 1885–91.) 7 Kensington Park-gardens, W.

Year of Election.

1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *Crookshank, E. M., M.B. Saint Hill, East Grinstead, Sussex.
1909. ‡Crosby, Rev. E. H. Lewis, B.D. 36 Rutland-square, Dublin.
1905. ‡Crosfield, Hugh T. Walden, Coombe-road, Croydon.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
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. 46 Lindfield-gardens, Hampstead, N.W.
1908. ‡Crossley, F. W. 30 Molesworth-street, Dublin.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1890. *Crowley, Ralph Henry, M.D. Sollershott W., Letchworth.
1910. ‡Crowther, Professor C., M.A., Ph.D. The University, Leeds.
1910. *Crowther, James Arnold. St. John's College, Cambridge.
1911. §Crush, S. T. Care of Messrs. Yarrow & Co., Ltd., Scotstoun West, Glasgow.
1883. *Culverwell, Edward P., M.A., Professor of Education in Trinity College, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1914. *Cuming, James. 65 William-street, Melbourne.
1914. *Cuming, W. Fehon. Hyde-street, Yarraville, Victoria.
1911. ‡Cumming, Alexander Charles, D.Sc. Chemistry Department, University of Edinburgh.
1911. §Cummins, Major H. A., M.D., C.M.G., Professor of Botany in University College, Cork.
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.
1911. ‡Cunningham, E. St. John's College, Cambridge.
1885. ‡Cunningham, J. T., M.A. 63 St. Mary's-grove, Chiswick, W.
1869. ‡Cunningham, Robert O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *Cunningham, Ven. Archdeacon W., D.D., D.Sc. (Pres. F, 1891, 1905.) Trinity College, Cambridge.
1900. *Cunnington, William A., M.A., Ph.D., F.Z.S. 25 Orlando-road, Clapham Common, S.W.
1912. §Cunynghame, Sir Henry H., K.C.B. (Pres. F, 1912.) Kingham Lodge, Chipping Norton.
1914. §Cunynghame, Lady. Kingham Lodge, Chipping Norton.
1914. §Curdie, Miss Jessie. Camperdown, Victoria
1913. ‡Currall, A. E. Streetsbrook-road, Solihull, Birmingham.
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.
1912. §Curtis, Charles. Field House, Cainscross, Stroud, Gloucestershire.
1915. §Curtis, Raymond. Highfield, Leek, Staffordshire.

Year of Election.

1907. ‡CUSHNY, ARTHUR R., M.D., F.R.S., Professor of Pharmacology in University College, Gower-street, W.C.
1913. ‡Cutler, A. E. 5 Charlotte-road, Edgbaston, Birmingham.
1913. ‡Czaplicka, Miss M. A. Somerford College, Oxford.

1910. ‡DAKIN, Dr. W. J., Professor of Biology in the University of Western Australia, Perth, Western Australia.
1914. ‡Dakin, Mrs. University of Western Australia, Perth, Western Australia.
1898. *DALBY, W. E., M.A., B.Sc., F.R.S., M.Inst.C.E. (Pres. G, 1910), Professor of Civil and Mechanical Engineering in the City and Guilds Engineering College, Imperial College of Science and Technology, 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.
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.
1914. §Danks, A. T. 391 Bourke-street, Melbourne.
1896. §Danson, F. C. Tower-buildings, Water-street, Liverpool.
1897. ‡Darbishire, F. V., B.A., Ph.D. Dorotheenstrasse 12, Dresden 20.
1903. ‡DARBISHIRE, Dr. OTTO V. The University, Bristol.
1916. §DARNELL, E. (LOCAL TREASURER, 1916.) Town Hall, Newcastle-on-Tyne.
1905. ‡Darwin, Lady. Newnham Grange, Cambridge.
1904. *Darwin, Charles Galton. Newnham Grange, Cambridge.
1882. *DARWIN, Sir FRANCIS, M.A., M.B., LL.D., D.Sc., F.R.S., F.L.S. (PRESIDENT, 1908; Pres. D, 1891; Pres. K, 1904; Council, 1882–84, 1897–1901.) 10 Madingley-road, Cambridge.
1878. *DARWIN, HORACE, M.A., F.R.S. The Orchard, Huntingdon-road, Cambridge.
1894. *DARWIN, Major LEONARD, F.R.G.S. (Pres. E, 1896; Council, 1899–1905.) 12 Egerton-place, South Kensington, S.W.
1910. ‡Dauncey, Mrs. Thursby. Lady Stewert, Heath-road, Weybridge.
1908. ‡*Davey, H.* 15 *Victoria-road, Brighton.*
1880. *DAVEY, HENRY, M.Inst.C.E. Conaways, Ewell, Surrey.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1914. ‡DAVID, Professor T. W. EDGEWORTH, C.M.G., D.Sc., F.R.S. The University, Sydney, N.S.W.
1904. ‡Davidge, H. T., B.Sc., Professor of Electricity in the Ordnance College, Woolwich.
1913. §Davidge, W. R., A.M.Inst.C.E. 63 Lewisham-park, S.E.
1913. ‡Davidge, Mrs. 63 Lewisham-park, S.E.
1909. ‡Davidson, A. R. 150 Stradbrooke-place, Winnipeg, Canada.
1912. ‡Davidson, Rev. J. The Manse, Douglas, Isle of Man.
1912. ‡Davidson, John, M.A., D.Ph. Training College, Small's Wynd, Dundee.
1902. *Davidson, S. C. Seacourt, Bangor, Co. Down.
1914. §Davidson, W. R. 15 Third-avenue, Hove.
1910. *Davie, Robert C., M.A., B.Sc. Royal Botanic Garden, Edinburgh
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1904. §Davies, Henry N., F.G.S. Ottery House, Bristol-road, Weston-super-Mare.

Year of Election.

1906. ‡Davies, S. H. Ryecroft, New Earswick, York.
1893. *Davies, Rev. T. Witton, B.A., Ph.D., D.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.
1896. *Davis, John Henry Grant. Dolobran, Wood Green, Wednesbury.
1910. ‡Davis, Captain John King. 9 Regent-street, W.
1905. ‡Davis, Luther. P.O. Box 898, Johannesburg.
1885. *Davis, Rev. Rudolf. Mornington, Elmbridge-road, Gloucester.
1886. ‡Davison, Charles, D.Sc. 16 Manor-road, Birmingham.
1905. ‡Davy, Joseph Burtt, F.R.G.S., F.L.S. Care of Messrs. Dulau & Co., 37 Soho-square, W.
1912. ‡Dawkins, Miss Ella Boyd. Fallowfield House, Fallowfield, Manchester.
1864. ‡Dawkins, W. Boyd, D.Sc., F.R.S., F.S.A., F.G.S. (Pres. C, 1888; Council, 1882–88.) Fallowfield House, Fallowfield, Manchester.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hurtlington Hall, Burnsall, Skipton-in-Craven.
1901. *Dawson, P. The Acre, Maryhill, Glasgow.
1905. ‡Dawson, Mrs. The Acre, Maryhill, Glasgow.
1912. *Dawson, Shepherd, M.A., B.Sc. Drumchapel, near Glasgow.
1906. §Dawson, William Clarke. Whitefriargate, Hull.
1859. *Dawson, Captain W. G. Abbots Morton, near Worcester.
1900. ‡Deacon, M. Whittington House, near Chesterfield.
1909. §Dean, George, F.R.G.S. 14 Evelyn-mansions, Queen's Club-gardens, W.
1915. §Dean, H. R. Pathological Department, The University, Manchester.
1901. *Deasy, Captain H. H. P. Cavalry Club, 127 Piccadilly, W.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1914. ‡Debenham, Frank. Caius College, Cambridge.
1915. §De Bolivar, Mrs. Anna. 75 Clarendon-road, High-street, Manchester.
1893. *Deeley, R. M., M.Inst.C.E., F.G.S. Abbeyfield, Salisbury-avenue, Harpenden, Herts.
1911. ‡Delahunt, C. G. The Municipal College, Portsmouth.
1878. ‡Delany, Very Rev. William, LL.D. University College, Dublin.
1915. §Delepiné, Sheridan. Public Health Laboratory, York-place, Manchester.
1908. *Delf, Miss E. M. Girton College, Cambridge.
1907. ‡*De Lisle, Mrs. Edwin. Charnwood Lodge, Coalville, Leicestershire.*
1914. §Delprat, G. D. Equitable-building, Collins-street, Melbourne.
1896. ‡Dempster, John. Tynron, Noctorum, Birkenhead.
1902. *Dendy, Arthur, D.Sc., F R S, F.L.S. (Pres. D, 1914; Council, 1912–), Professor of Zoology in King's College, London, W.C.
1914. ‡Dendy, Miss. Vale Lodge, Hampstead, N.W.
1913. *Denman, Thomas Hercy. 17 Churchgate, Retford, Nottinghamshire.
1908. ‡Dennehy, W. F. 23 Leeson-park, Dublin.
1889. *Denny, Alfred, M.Sc., F.L S., Professor of Zoology in the University of Sheffield. Cliffside, Ranmoor-crescent, Sheffield.
1909. §Dent, Edward, M.A. 2 Carlos-place, W.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Junior Carlton Club, Pall Mall, S.W.

Year of Election.

1907. *Desch, Cecil H., D.Sc., Ph.D. 3 Kelvinside-terrace North, Glasgow.
1908. ‡*Despard, Miss Kathleen M.* 6 *Sutton Court-mansions, Grove Park-terrace, Chiswick, W.*
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
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.
1884. *Dewar, William, M.A. Horton House, Rugby.
1914. ‡Dickinson, Miss Desiree. Menzies' Hotel, Melbourne
1908. §Dicks, Henry. Haslecourt, Horsell, Woking.
1904. ‡Dickson, Right Hon. Charles Scott, K.C., LL.D., M.P. 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. (Pres. E, 1913; Council, 1915-), Professor of Geography in University College, Reading. 160 Castle-hill, Reading.
1902. §Dickson, James D. Hamilton, M.A., F.R.S.E. 6 Cranmer-road, Cambridge.
1913. *Dickson, T. W. 60 Jeffrey's-road, Clapham, S.W.
1908. ‡Dines, J. S. Pyrton Hill, Watlington.
1901. §Dines, W. H, B A., F R.S. Benson, Wallingford, Berks.
1905. §Dixey, F. A., M.A., M.D., F.R.S. (Council, 1913- .) Wadham College, Oxford.
1915. §Dixon, Miss A. Broadwater, 43 Pine-road, Didsbury.
1899. *Dixon, A. C., D.Sc., F.R.S., Professor of Mathematics in Queen's University, Belfast. Hurstwood, Malone Park, Belfast.
1874. *Dixon, A. E., M.D., Professor of Chemistry in University 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, Cumberland.
1908. ‡Dixon, Edward K., M.E., M.Inst.C.E. Castlebar, Co. Mayo.
1888. ‡Dixon, Edward T. Racketts, Hythe, Hampshire.
1908. *Dixon, Ernest, B.Sc., F.G.S. The Museum, Jermyn-street, S.W.
1900. *Dixon, Lieut.-Colonel George, M.A. Fern Bank, St. Bees, Cumberland.
1879. *Dixon, Harold B., M.A., F.R.S., F.C.S. (Pres. B, 1894; Council, 1913-), Professor of Chemistry in the Victoria University, Manchester.
1914. §Dixon, Mrs. H. B., Beechey House, Wilbraham-road, Fallowfield, Manchester.
1902. ‡Dixon, Henry H., D.Sc., F.R.S., Professor of Botany in the University of Dublin. Clevedon, Temple-road, Dublin.
1913. ‡Dixon, S. M., M.A., M.Inst.C.E., Professor of Civil Engineering in the Imperial College of Science and Technology, London, S.W.
1908. Dixon, Walter, F.R.M.S. Derwent, 30 Kelvinside-gardens, Glasgow.
1907. *Dixon, Professor Walter E., F.R.S. The Museums, Cambridge.
1914. ‡Dixon, Mrs. W. E. The Grove, Whittlesford, Cambridge.
1902. ‡*Dixon, W. V. Scotch Quarter, Carrickfergus.*
1896. §Dixon-Nuttall, F. R. Ingleholme, Eccleston Park, Prescot.
1890. ‡Dobbie, Sir James J., D.Sc., LL.D., F.R.S., Principal of the Government Laboratories, 13 Clement's Inn-passage, W.C.

Year of Election.

1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A., J.P., D.L. Castle Dobbs, Carrickfergus, Co. Antrim.
1902. ‡Dobbs, F. W., M.A. Eton College, Windsor.
1914. ‡Docker, His Honour Judge E. B., M.A. Mostyn, Elizabeth Bay, Sydney, N.S.W.
1908. ‡Dodd, Hon. Mr. Justice. 26 Fitzwilliam-square, Dublin.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1912. ‡Don, A. W. R. The Lodge, Broughty Ferry, Forfarshire.
1912. ‡*Don, Alexander, M.A., F.R.C.S. Park House, Nethergate, Dundee.*
1912. ‡Don, Robert Bogle, M.A. The Lodge, Broughty Ferry, Forfarshire.
1904. ‡Doncaster, Leonard, M.A. Museum of Zoology, Cambridge.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1901. ‡Donnan, F. G., M.A., Ph.D., F.R.S., Professor of Chemistry in University College, Gower-street, W.C.
1915. §Doodson, Arthur T., M.Sc. 1 Manor-road, Shaw, Lancashire.
1905 §Dornan, Rev. S. S. P.O. Box 510, Bulawayo, South Rhodesia, South Africa.
1863. *Doughty, Charles Montagu. 26 Grange-road, Eastbourne.
1909. ‡Douglas, A. J., M.D. City Health Department, Winnipeg, Canada.
1909. *Douglas, James. 99 John-street, New York, U.S.A.
1912. ‡Doune, Lord. Kinfauns Castle, Perth.
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. Landhurst Wood, Hartfield, Sussex.
1913. ‡Dracopoli, J. N. Pollard's Wood Grange, Chalfont St. Giles, Buckinghamshire.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1912. §Drever, James, M.A., B.Sc. 36 Morningside-grove, Edinburgh.
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. Hatherley Court, Cheltenham.
1906. *Drew, Mrs. Hatherley Court, Cheltenham.
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.
1909. *Drugman, Julien, Ph.D., M.Sc. 117 Rue Gachard, Brussels.
1907. †Drysdale, Charles V., D.Sc. Queen Anne's-chambers, S.W.
1892. ‡Du Bois, Professor Dr. H. Herwarthstrasse 4, Berlin, N.W.
1856. *Ducie, The Right Hon. Henry John Reynolds Moreton, Earl of, G.C.V.O., 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.
1914. ‡Duff, Frank Gee. 31 Queen-street, Melbourne.
1914. ‡Duffield, D. Walter. 13 Cowra-chambers, Grenfell-street, Adelaide, South Australia.
1912. §Duffield, Francis A., M.B. Home Lea, Four Oaks, Sutton Coldfield.
1904. *Duffield, Professor W. Geoffrey, D.Sc. University College, Reading.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1899. *Dugdale-Bradley, J. W., M.Inst.C.E. Westminster City Hall, Charing Cross-road, W.C.

Year of Election.

1911. ‡Dummer, John. 85 Cottage-grove, Southsea.
1914. ‡Dun, W. S. Mines Department, Sydney, N.S.W.
1909. ‡Duncan, D. M., M.A. 83 Spence-street, Winnipeg, Canada.
1910. ‡Dunn, Rev. J. Road Hill Vicarage, Bath.
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, Wyndham R., C.M.G., M.A., LL.D., F.R.S., F.C.S. (Pres. B, 1906; Council, 1905–08), Director of the Imperial Institute, S.W.
1911. ‡Dupree, Colonel Sir W. T. Craneswater, Southsea.
1913. §Durie, William. 31 Priory-road, Bedford Park, Chiswick, W.
1914. §Du Toit, A. L., D.Sc. South African Museum, Cape Town.
1914. ‡Du Toit, Mrs. South African Museum, Cape Town.
1905. §Dutton, C. L. O'Brien. High Commissioner's Office, Pretoria.
1910. ‡Dutton, F. V., B.Sc. County Agricultural Laboratories, Richmond-road, Exeter.
1895. *Dwerryhouse, Arthur R., D.Sc., F.G.S. Deraness, Deramore Park, Belfast.
1911. ‡Dye, Charles. Woodcrofts, London-road, Portsmouth.
1885. *Dyer, Henry, M.A., D.Sc., LL.D. 8 Highburgh-terrace, Dowanhill, Glasgow.
1895. §Dymond, Thomas S., F.C.S. Savile Club, Piccadilly, W.
1905. *Dyson, Sir F. W., M.A., LL.D., F.R.S. (Pres. A, 1915; Council, 1905–11, 1914–), Astronomer Royal. Royal Observatory, Greenwich, S.E.
1910. ‡Dyson, W. H. Maltby Colliery, near Rotherham, Yorkshire.

1912. ‡Earland, Arthur, F.R.M.S. 34 Granville-road, Watford.
1899. ‡East, W. H. Municipal School of Art, Science, and Technology, Dover.
1909. *Easterbrook, C. C., M.A., M.D. Crichton Royal Institution, Dumfries.
1893. *Ebbs, Alfred B. Tuborg, Plaistow-lane, Bromley, Kent.
1906. *Ebbs, Mrs. A. B. Tuborg, Plaistow-lane, Bromley, Kent.
1909. ‡Eccles, J. R. Gresham's School, Holt, Norfolk.
1903. *Eccles, W. H., D.Sc. 26 Ridgmount-gardens, Gower-street, W.C.
1908. *Eddington, A. S., M.A., M.Sc., F.R.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. The Observatory, Cambridge.
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.
1911. *Edge, S. F. Gallops Homestead, Ditchling, Sussex.
1911. *Edgell, Miss Beatrice. Bedford College, Regent's Park, N.W.
1884. *Edgell, Rev. R. Arnold, M.A. Beckley Rectory, East Sussex.
1887. §Edgeworth, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889; Council, 1879–86, 1891–98), Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Moulsecombe-place, Brighton.

Year of Election.

1901. *Edridge-Green, F. W., M.D., F.R.C.S. 99 Walm-lane, Willesden Green, N.W.
1914. ‡Edwards, A. F. Chemical Department, The University, Manchester.
1915. §Edwards, C. A. 26 Lyndhurst-road, Withington, Manchester.
1899. §Edwards, E. J., Assoc.M.Inst.C.E. 13 Acris-street, Wandsworth Common, S.W.
1913. §Edwards, E. J. Royal Technical College, Glasgow.
1901. ‡Eggar, W. D. Eton College, Windsor.
1909. ‡Eggertson, Arni. 120 Emily-street, Winnipeg, Canada.
1909. §Ehrenborg, G. B. 2 College-road, Clifton, Bristol.
1907. *Elderton, W. Palin. 24 Mount Ephraim-road, Streatham, S.W.
1890. ‡Elford, Percy. 115 Woodstock-road, Oxford.
1913. ‡Elkington, Herbert F. Clunes, Wentworth-road, Sutton Coldfield.
1901. *Elles, Miss Gertrude L., D.Sc. Newnham College, Cambridge.
1915. §Ellinger, Barnard, F.S.S. 28 Oxford-street, Manchester.
1904. ‡Elliot, Miss Agnes I. M. Newnham College, Cambridge.
1904. ‡Elliot, R. H. Clifton Park, Kelso, N.B.
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.
1912. §Elliott, Dr. W. T., F.Z.S. 21 Bennett's-hill, Birmingham.
1906. *Ellis, David, D.Sc., Ph.D. Royal Technical College, Glasgow.
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1906. §Ellis, Herbert. The Gynsills, Groby-road, Leicester.
1913. ‡Ellis, Herbert Willoughby, A.M.Inst.C.E. Holly Hill, Berkswell, Warwickshire.
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.
1910. ‡Elmhirst, Richard. Marine Biological Station, Millport.
1911. ‡Elwes, H. J., F.R.S. Colesborne Park, near Cheltenham.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1905. ‡Epps, Mrs. Dunhurst, Petersfield, Hampshire.
1894. ‡Erskine-Murray, J., D.Sc., F.R.S.E. 4 Great Winchester-street, E.C.
1914. ‡Erson, Dr. E. G. Leger. 123 Collins-street, Melbourne.
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.
1911. ‡Etherton, G. Hammond. (Local Sec. 1911.) Town Hall, Portsmouth.
1897. *Evans, Lady. Care of Union of London and Smiths Bank, Berkhamsted, Herts.
1889. *Evans, A. H., M.A. 9 Harvey-road, Cambridge.
1905. ‡Evans, Mrs. A. H. 9 Harvey-road, Cambridge.
1870. *Evans, Sir Arthur John, M.A., LL.D., F.R.S., F.S.A. (President Elect; Pres. H, 1896.) Youlbury, Abingdon.
1908. ‡Evans, Rev. Henry, D.D., Commissioner of National Education, Ireland. Blackrock, Co. Dublin.

Year of Election.

1887. *Evans, Mrs. Isabel. Lyndhurst, Upper Chorlton-road, Whalley Range, Manchester.
1913. §Evans, J. Jameson. 41 Newhall-street, Birmingham.
1910. *Evans, John W., D.Sc., LL.B., F.G.S. 75 Craven Park-road, Harlesden, N.W.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1905. ‡Evans, R. O. Ll. Broom Hall, Chwilog, R.S.O., Carnarvonshire
1905. ‡Evans, T. H. 9 Harvey-road, Cambridge.
1910. ‡Evans, T. J. The University, Sheffield.
1865. *Evans, William. The Spring, Kenilworth.
1909. ‡Evans, W. Sanford, M.A. (Local Sec. 1909.) 43 Edmonton street, Winnipeg.
1902. *Everett, Percy W. Oaklands, Elstree, Hertfordshire.
1883. ‡Eves, Miss Florence. Uxbridge.
1914. ‡Ewart, Professor A. J., D.Sc. The University, Melbourne.
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.
1913. *Ewen, J. T. 104 King's-gate, Aberdeen.
1913. *Ewen, Mrs. J. T. 104 King's-gate, Aberdeen.
1876. *Ewing, Sir James Alfred, K.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. Froghole, Edenbridge, Kent.
1914 §Ewing, Mrs. Peter. The Frond, Uddingston, Glasgow.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1912. §Eyre, Dr. J. Vargas. South-Eastern Agricultural College, Wye, Kent.

Eyton, Charles. Hendred House, Abingdon

1906. *Faber, George D. 14 Grosvenor-square, W.
1901. *Fairgrieve, M. McCallum. 37 Queen's-crescent, Edinburgh.
1865. *Fairley, Thomas, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1910. §Falconer, J. D., M.A., D.Sc. Geographical Department, The University, Glasgow.
1908. ‡Falconer, Robert A., M.A. 44 Merrion-square, Dublin.
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Cheshire.
1902. §Fallaize, E. N., B.A. Vinchelez, Chase Court-gardens, Windmill-hill, Enfield.
1907. *Fantham, H. B., M.A., D.Sc. 100 Mawson-road, Cambridge.
1902. ‡Faren, William. 11 Mount Charles, Belfast.
1892. *Farmer, J. Bretland, M.A., F.R.S., F.L.S. (Pres. K, 1907; Council, 1912–14.) South Park, Gerrard's Cross.
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.
1913. ‡Farrow, F. D. Rhodes University College, Grahamstown, South Africa
1903. §Faulkner, Joseph M. 17 Great Ducie-street, Strangeways, Manchester.
1913. §Fawcett, C. B. University College, Southampton.
1890. *Fawcett, F. B. 1 Rockleaze-avenue, Sneyd Park, Bristol.
1906. §Fawcett, Henry Hargreave. Thorncombe, near Chard, Somerset.

Year of Election.

1900. ‡FAWCETT, J. E., J.P. (Local Sec. 1900.) Low Royd, Apperley Bridge, Bradford.
1902. *Fawsitt, C. E., Ph.D., Professor of Chemistry in the University of Sydney, New South Wales.
1911. *Fay, Mrs. A. Q. Chedworth, Rustat-road, Cambridge.
1909. *Fay, Charles Ryle, M.A. Christ's College, Cambridge.
1906. *Fearnsides, Edwin E., M.A., M.B., B.Sc. London Hospital, E.
1901. *FEARNSIDES, W. G., M.A., F.G.S., Sorby Professor of Geology in the University of Sheffield. 10 Silver Birch-avenue, Fulwood, Sheffield.
1910. *Fearnsides, Mrs. 10 Silver Birch-avenue, Fulwood, Sheffield.
1905. ‡Feilden, Colonel H. W., C.B., F.R.G.S., F.G.S. Burwash, Sussex.
1900. *Fennell, William John. 2 Wellington-place, Belfast.
1904. ‡Fenton, H. J. H., M.A., Sc.D., F.R.S. 19 Brookside, Cambridge.
1914. §Ferguson, E. R. Gordon-street, Footscray, Victoria.
1871. *FERGUSON, JOHN, M.A., LL.D., F.R.S.E., F.S.A., F.C.S. 13 Newton-place, Glasgow.
1901. ‡Ferguson, R. W. 16 Linden-road, Bournville, near Birmingham.
1863. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1910. *Ferranti, S. Z. de, M.Inst C.E. Grindleford, near Sheffield.
1905. *FERRAR, H. T., M.A., F.G.S. Care of A. Anderson, Esq., St. Martin's, Christchurch, New Zealand.
1914. ‡Ferrar, Mrs. Care of A. Anderson, Esq., St. Martin's, Christchurch, New Zealand.
1873. ‡FERRIER, Sir DAVID, M.A., M.D., LL.D., F.R.S. 34 Cavendish-square, W.
1909. ‡Fetherstonhaugh, Professor Edward P., B.Sc. 119 Betourney-street, Winnipeg, Canada.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1915. §Field, A. B. Kingslea, Marple, near Stockport.
1913. ‡Field, Miss E. E. Hollywood, Egham Hill, Surrey.
1897. ‡Field, George Wilton, Ph.D. Room 158, State House, Boston, Massachusetts, U.S.A.
1907. *Fields, Professor J. C., F.R.S. The University, Toronto, Canada.
1906. §FILON, L. N. G., D.Sc., F.R.S., Professor of Applied Mathematics in the University of London. Lynton, Haling Park-road, Croydon.
1905. ‡Fincham, G. H. Hopewell, Invami, Cape Colony.
1905. §Findlay, Alexander, M.A., Ph.D., D.Sc., Professor of Chemistry in University College, Aberystwyth.
1904. *Findlay, J. J., Ph.D., Professor of Education in the Victoria University, Manchester. Ruperra, Victoria Park, Manchester.
1912. §Finlayson, Daniel, F.L.S. Seed Testing Laboratory, Wood Green, N.
1902. ‡Finnegan, J., M.A., B.Sc. Kelvin House, Botanic-avenue, Belfast.
1902. ‡*Fisher, J. R. Cranfield, Fortwilliam Park, Belfast.*
1909. ‡Fisher, James, K.C. 216 Portage-avenue, Winnipeg, Canada.
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. Boarzell, Hurst Green, Sussex.
1885. *FITZGERALD, Professor MAURICE, B.A. (Local Sec. 1902.) Fairholme, Monkstown, Co. Dublin.
1894. ‡FITZMAURICE, Sir MAURICE, C.M.G., M.Inst.C.E. London County Council, Spring-gardens, S.W.

Year of Election

1888. *Fitzpatrick, Rev. Thomas C., President of Queens' College, Cambridge.
1904. ‡Flather, J. H., M.A. Camden House, 90 Hills-road, Cambridge.
1915. §Fleck, Alexander. Blenheim-avenue, Stepps, near Glasgow.
1915. *Fleming, Arthur P. M. West Gables, Hale-road, Hale, Cheshire.
1913. ‡Fleming, Professor J. A., D.Sc., F.R.S. University College, Gower-street, W.C.
1904. ‡Fleming, James. 25 Kelvinside-terrace South, Glasgow.
1892. ‡Fletcher, George, F.G.S. Mona, Shankhill, Co. Dublin.
1888. *Fletcher, Sir Lazarus, M.A., Ph.D., F.R.S., F.G.S., F.C.S. (Pres. C, 1894), Director of the Natural History Museum, Cromwell-road, S.W. 35 Woodville-gardens, Ealing, W.
1915. §Fletcher, Leonard R. Woodfields, Leigh, Lancashire.
1908. *Fletcher, W. H. B. Aldwick Manor, Bognor, Sussex.
1901. ‡Flett, J. S., M.A., D.Sc., F.R.S., F.R.S.E. Geological Survey Office, 33 George-square, Edinburgh.
1906. *Fleure, H. J., D.Sc., Professor of Zoology and Geology in University College, Aberystwyth.
1905. *Flint, Rev. W., D.D. Houses of Parliament, Cape Town.
1913. *Florence, P. Sargant, B.A. Caius College, Cambridge.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1890. *Flux, A. W., M.A. Board of Trade, Gwydyr House, Whitehall, S.W.
1914. §Flynn, Professor T. Thomson. University of Tasmania, Hobart.
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
1911. ‡Foran, Charles. 72 Elm-grove, Southsea.
1906. §Forbes, Charles Mansfeldt. 14 New-street, York.
1914. ‡Forbes, E. J. P.O. Box 1604, Sydney, N.S.W.
1914. ‡Forbes, Mrs. E. J. P.O. Box 1604, Sydney, N.S.W.
1873. *Forbes, George, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 11 Little College-street, Westminster, S.W.
1883. ‡Forbes, Henry O., LL.D., F.Z.S. Redcliffe, Beaconsfield, Bucks.
1905. ‡Forbes, Lieut.-Colonel W. Lachlan. Army and Navy Club, Pall Mall, S.W.
1875. *Fordham, Sir George. Odsey, Ashwell, Baldock, Herts.
1909. ‡Forget, The Hon. A. E. Regina, Saskatchewan, Canada.
1887. ‡Forrest, The Right Hon. Sir John, G.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.
1915. §Forrester, Robert B. Marischal College, Aberdeen.
1902. *Forster, M. O., Ph.D., D.Sc., F.R.S. 84 Cornwall-gardens, S.W.
1883. ‡Forsyth, Professor A. R., M.A., D.Sc., F.R.S. (Pres. A, 1897, 1905; Council, 1907-09.) The Manor House, Marylebone, N.W.
1911. ‡Foster, F. G. Ivydale, London-road, Portsmouth.
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, W.*
1901. ‡Foster, T. Gregory, Ph.D., Provost of University College, London. University College, Gower-street, W.C.
1911. ‡Foster, Sir T. Scott, J.P. Town Hall, Portsmouth.
1911. ‡Foster, Lady Scott. Braemar, St. Helen's-parade, Southsea.
1903. ‡Fourcade, H. G. P.O., Storms River, Humansdorp, Cape Colony.

Year of Election.

1909. §Fowlds, Mrs. 65 Devonshire-street, Keighley, Yorkshire.
1912. ‡Fowler, A., F R.S., Assistant Professor of Physics in the Imperial College of Science and Technology, S.W. 19 Rusthall-avenue, Bedford Park, W.
1883. *Fox, Charles. The Pynes, Warlingham-on-the-Hill, Surrey.
1883. ‡Fox, Sir Charles Douglas, M.Inst.C.E. (Pres. G, 1896.) Crosse Keys House, 56 Moorgate-street, E.C.
1904. *Fox, Charles J. J., B.Sc., Ph.D., Professor of Chemistry in the Presidency College of Science, Poona, India.
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.
1900. *Fox, Thomas. Old Way House, Wellington, Somerset.
1909. *Fox, Wilson Lloyd. Carmino, Falmouth.
1908. §Foxley, Miss Barbara, M.A. 5 Norton Way North, Letchworth.
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, D.Sc., F.L.S. Westfield College, Hampstead, N.W.
1887. *Frankland, Percy F., Ph.D., B.Sc., F.R.S. (Pres. B, 1901), Professor of Chemistry in the University of Birmingham.
1913. §Franklin, Cyril H. H 38 Croydon-road, Croydon, Sydney, N.S.W.
1910. Franklin, Sir George, Litt.D. Tapton Hall, Sheffield.
1911. ‡Fraser, Dr. A. Mearns. (Local Sec. 1911.) Town Hall, Portsmouth.
1911. ‡Fraser, Mrs. A. Mearns. Cheyne Lodge, St. Ronan's-road, Portsmouth.
1895. ‡Fraser, Alexander. 63 Church-street, Inverness.
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.
1911. ‡Freeman, Oliver, B.Sc. The Municipal College, Portsmouth.
1906. §French, Fleet-Surgeon A. M. Langley, Beaufort-road, Kingston-on-Thames.
1909. ‡French, Mrs. Harriet A. Suite E, Gline's-block, Portage-avenue, Winnipeg, Canada.
1912. §French, Mrs. Harvey. Hambledon Lodge, Childe Okeford, Blandford. 4 Ashburn-place, S.W.
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.
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.
1912. §Frodsham, Miss Margaret, B.Sc. The College School, 34 Cathedral-road, Cardiff.
1892. *Frost, Edmund, M.D. Chesterfield-road, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1911. ‡Frost, M. E. P. H.M. Dockyard, Portsmouth.
1887. *Frost, Robert, B.Sc. 55 Kensington-court, W.
1898. ‡Fry, The Right Hon. Sir Edward, G.C.B., D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1908. ‡Fry, M. W. J., M.A. 39 Trinity College, Dublin.
1905. *Fry, Sir William, J.P., F.R.G.S. Wilton House, Merrion-road, Dublin.

Year of Election.

1898. ‡Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1912. §Fulton, Angus R., B.Sc. University College, Dundee.
1913. *Fyson, Philip Furley, B.A., F.L.S. Elmley Lovett, Droitwich.

1910. ‡Gadow, H. F., Ph.D., F.R.S. (Pres. D, 1913). Zoological Laboratory, Cambridge.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1906. ‡Gajjar, Professor T. K., M.A., B.Sc. 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 of Good Hope.
1913. §Gamble, F. W., D.Sc., F.R.S. (Local Sec., 1913), Professor of Zoology and Comparative Anatomy in the University of Birmingham. Scarsfields House, Alvechurch, Worcestershire.
1888. *Gamble, J. Sykes, C.I.E., M.A., F.R.S., F.L.S. Highfield, East Liss, Hants.
1911. ‡Garbett, Rev. C. F., M.A. The Vicarage, Fratton-road, Portsmouth.
1899. *Garcke, E. Ditton House, near Maidenhead.
1898. ‡Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
1911. ‡Gardiner, C. I., M.A., F.G.S. 6 Paragon-parade, Cheltenham.
1912. §Gardiner, F. A., F.L.S. Inversnaid, West Heath-avenue, N.W.
1905. ‡Gardiner, J. H. 59 Wroughton-road, Balham, S.W.
1900. ‡Gardiner, J. Stanley, M.A., F.R.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Zoological Laboratory, 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.
1912. §Gardner, Willoughby, F.L.S. Y Berlfa, Deganwy, North Wales.
1912. §Garfitt, G. A. Cartledge Hall, Holmesfield, near Sheffield.
1915. §Garforth, William. Snydale Hall, near Pontefract.
1913. *Garnett, Principal J. C. Maxwell, M.A. (Local Secretary, 1915.) Westfield, Victoria Park, Manchester.
1905. ‡Garnett, Mrs. Maxwell, F.Z.S. Westfield, Victoria Park, Manchester.
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, T. James, M.A. Bedales 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., D.Sc., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1889. ‡Garwood, E. J., M.A., F.R.S., F.G.S. (Pres. C, 1913), Professor of Geology in the University of London. University College, Gower-street, W.C.

Year of Election.

1905. ‡Gaskell, Miss C. J. The Uplands, Great Shelford, Cambridge.
1905. ‡Gaskell, Miss M. A. The Uplands, Great Shelford, Cambridge.
1906. ‡Gaster, Leon. 32 Victoria-street, S.W.
1913. ‡Gates, R. R., Ph.D., F.L.S. 14 Well-walk, Hampstead, N.W.
1911. ‡Gates, W. 'Evening News' Office, Portsmouth.
1912. §Gavin, W., M.A. The Farms Offices, Blenheim Park, Woodstock.
1905. *Gearon, Miss Susan. 26 Oakdale-road, Streatham, S.W.
1885. ‡Geddes, Professor Patrick, F.R.S.E. Outlook Tower, Edinburgh.
1887. ‡Gee, W. W. Haldane. Oak Lea, Whalley-avenue, Sale.
1867. ‡Geikie, Sir Archibald, O.M., K.C.B., LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S. (President, 1892; Pres. C, 1867, 1871, 1899; Council, 1888–1891.) Shepherd's Down, Haslemere, Surrey.
1913. §Geldart, Miss Alice M. 2 Cotman-road, Norwich.
1898. *Gemmill, James F., M.A., M.D. 12 Anne-street, Hillhead, Glasgow.
1882. *Genese, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1905 ‡Gentleman, Miss A. A. 9 Abercromby-place, Stirling.
1912. *George, H. Trevelyan, M.A., M.R.C.S., L.R.C.P. 33 Ampthill-square, N.W.
1902. *Gepp, Antony, M.A., F.L.S. British Museum (Natural History), Cromwell-road, S.W.
1899. *Gepp, Mrs. A. British Museum (Natural History), Cromwell-road, S.W.
1913. §Gerich, Miss Emma A. P. Strand Palace Hotel, Strand, W.C.
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1909. ‡Gibbons, W. M., M.A. (Local Sec. 1910.) The University, Sheffield.
1905. ‡Gibbs, Miss Lilian S., F.L.S. 22 South-street, Thurloe-square, S.W.
1912. ‡Gibson, A. H., D.Sc., Professor of Engineering in University College, Dundee.
1914. §Gibson, A. J., Ph.D. Central Sugar Mills, Brisbane, Australia.
1915. §Gibson, Charles R. Lynton, Causewood, Pollokshaws, Glasgow.
1912. ‡Gibson, G. E., Ph.D., B.Sc. 16 Woodhall-terrace, Juniper Green.
1901. ‡Gibson, Professor George A., M.A. 10 The University, Glasgow.
1904. *Gibson, Mrs. Margaret D., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1912. *Gibson, Miss Mary H., M.A., Ph.D. 75 Colum-road, Cardiff.
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.
1898. *Gifford, J. William, F.R A.S. 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.
1911. ‡Gill, Rev. H. V., S.J. Milltown Park, Clonskea, Co. Dublin.
1902 ‡Gill, James F. 72 Strand-road, Bootle, Liverpool.
1908. ‡Gill, T. P. Department of Agriculture and Technical Instruction for Ireland, Dublin.
1913. *Gillett, Joseph A., B.A. Woodgreen, Banbury.

Year of Election.

1913. ‡Gillmor, R. E. 57 Victoria-street, S.W.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1907. ‡Gilmour, S. C. 25 Cumberland-road, Acton, W.
1908. ‡*Gilmour, T. L.* 1 *St. John's Wood Park, N.W.*
1913. §Gilson, R. Cary, M.A. King Edward's School, Birmingham.
1913. ‡Gimingham, C. T., F.I.C. Research Station, Long Ashton, Bristol.
1893. *Gimingham, Edward. Croyland, Clapton Common, N.E.
1904. ‡Ginn, S. R., D.L. (Local Sec. 1904.) Brookfield, Trumpington-road, Cambridge.
1884. ‡Girdwood, G. P., M.D. 615 University-street, Montreal, Canada.
1886. *Gisborne, Hartley, M.Can.S.C.E. Yoxall, Rural Route No. 1—Ladysmith, British Columbia, Canada.
1883. *Gladstone, Miss. 19 Chepstow-villas, Bayswater, W.
1871. *Glaisher, J. W. L., M.A., Sc.D., F.R.S., F.R.A.S. (Pres. A, 1890; Council, 1878–86.) Trinity College, Cambridge.
1881. *Glazebrook, R. T., C.B., M.A., Sc.D., F.R.S. (Pres. A, 1893; Council, 1890–94, 1905–11), Director of the National Physical Laboratory. Bushy House, Teddington, Middlesex.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
1915. §Glover, James. Lowton House, Lowton, Lancashire.
Glover, Thomas. 124 Manchester-road, Southport.
1915. §Godlee, Francis. 8 Minshall-street, Manchester.
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. 45 Pont-street, S.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. 8 Hurst Close, Bigwood-road, Hampstead Garden Suburb, N.W.
1914. ‡Gold, Mrs. 8 Hurst Close, Bigwood-road, Hampstead Garden Suburb, N.W.
1906. ‡Goldie, Right Hon. Sir George D. T., K.C.M.G., D.C.L., F.R.S. (Pres. E, 1906; Council, 1906–07.) Naval and Military Club, 94 Piccadilly, W.
1910. ‡Golding, John, F.I.C. University College, Reading.
1913. ‡Golding, Mrs. University College, Reading.
1890. *Gonner, E. C. K., M.A. (Pres. F, 1897, 1914), Professor of Economic Science in the University of Liverpool. Undercliff, West Kirby, Cheshire.
1909. ‡Goodair, Thomas. 303 Kennedy-street, Winnipeg, Canada.
1912. §Goodman, Sydney C. N., B.A. 1 Brick-court, Temple, E.C.
1907. §Goodrich, E. S., M.A., F.R.S., F.L.S. 53 Banbury-road, Oxford.
1908. ‡Goodrich, Mrs., D.Sc. 53 Banbury-road, Oxford.
1884. *Goodridge, Richard E. W. P.O. Box 36, Coleraine, Minnesota, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1909. ‡Gordon, Rev. Charles W. 567 Broadway, Winnipeg, Canada
1909. ‡Gordon, J. T. 147 Hargrave-street, Winnipeg, Canada.
1909. ‡Gordon, Mrs. J. T. 147 Hargrave-street, Winnipeg, Canada.
1911. *Gordon, J. W. 113 Broadhurst-gardens, Hampstead, N.W.
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
1910. *Gordon, Vivian. Avonside Engine Works, Fishponds, Bristol.
1912. §Gordon, W. T. Geological Department, King's College, Strand, W.C.
1901. ‡Gorst, Right Hon. Sir John E., M.A., K.C., M.P., F.R.S. (Pres. L, 1901.) 84 Campden Hill Court, W.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1901. ‡Gourlay, Robert. 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. P.O. Box 178, Khartoum, Sudan.
1886. ‡Grabham, Michael C., M.D. Madeira.
1909. ‡Grace, J. H., M.A., F.R.S. Peterhouse, Cambridge.
1909. ‡Graham, Herbert W. 329 Kennedy-street, Winnipeg, Canada.
1902. *Graham, William, M.D. Purdysburn House, Belfast.
1914. ‡Graham, Mrs. Purdysburn House, Belfast.
1875. ‡Grahame, James. (Local Sec. 1876.) Care of Messrs. Grahame, Crums, & Connal, 34 West George-street, Glasgow.
1904. §Gramont, Comte Arnaud de, D.Sc., Memb. de l'Institut de France. 179 rue de l'Université, Paris.
1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.
1914. ‡Grant, Kerr, M.Sc., Professor of Physics in the University of Adelaide, South Australia.
1908. *Grant, Professor W. L. Queen's University, Kingston, Ontario.
1914. ‡Grasby, W. C. Care of G. J. W. Grasby, Esq., Grenfell-street, Adelaide, South Australia.
1890. ‡Gray, Andrew, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1903. §Gray, Ernest, M.A. 104 Tulse-hill, S.W.
1904. ‡Gray, Rev. H. B., D.D. (Pres. L, 1909). Pincroyd, Lower Bourne, Farnham.
1892. *Gray, James Hunter, M.A., B.Sc. 3 Crown Office-row, Temple, E.C.
1887. ‡Gray, Joseph W., F.G.S. 6 Richmond Park-crescent, Bournemouth.
1901. ‡Gray, R. Whytlaw. University College, W.C.
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.
1910. ‡Greaves, R. H., B.Sc. 12 St. John's-crescent, Cardiff.
1904. *Green, Professor A. G., M.Sc. The Old Gardens, Cardigan-road, Headingley, Leeds.
1904. §Green, F. W. 5 Wordsworth-grove, Cambridge.
1914. ‡Green, Heber, D.Sc. The University, Melbourne.
1906. §Green, J. A., M.A., Professor of Education in the University of Sheffield.
1908. ‡Green, Rev. William Spotswood, C.B., F.R.G.S. 5 Cowper-villas, Cowper-road, Dublin.
1916. §Greener, T. Y. Urpeth Lodge, Beamish, S.O., Co. Durham.
1909. ‡Greenfield, Joseph. P.O. Box 2935, Winnipeg, Canada.
1882. ‡Greenhill, Sir A. G., M.A., F.R.S. 1 Staple Inn, W.C.
1905. ‡Greenhill, William. 6A George-street, Edinburgh.
1915. §Greenhow, J. H. 46 Princess-street, Manchester.

Year of Election.

1913. *Greenland, Miss Lucy Maud. St. Hilda's, Hornsea, East Yorkshire.
1898. *GREENLY, EDWARD, F.G.S. Achnashean, near Bangor, North Wales.
1906. ‡Greenwood, Sir Hamar, Bart., M.P. National Liberal Club, Whitehall-place, S.W.
1915. §Greenwood, William. 35 Belgrave-road. Oldham.
1915. §Greg, Henry P. Lode Hill, Styal.
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. Walcot, Blyth-road, Bromley, Kent.
1904. *GREGORY, R. P., M.A. St. John's College, Cambridge.
1914. ‡Gregory, Miss V. J. The University, Glasgow.
1914. ‡Grew, Mrs. 30 Cheyne-row, S.W.
1894. *Griffith, C. L. T., Assoc.M.Inst.C.E. Gayton Corner, Harrow.
1908. §Griffith, Sir John P., M.Inst.C.E. Rathmines Castle, Rathmines, Dublin.
1884. ‡GRIFFITHS, E. H., M.A., D.Sc., F.R.S. (Pres. A, 1906; Pres. L, 1913; Council, 1911–), Principal of University College, Cardiff.
1884. ‡Griffiths, Mrs. University College, Cardiff.
1903. ‡Griffiths, Thomas P., J.P. 101 Manchester-road, Southport.
1888. *Grimshaw, James Walter, M.Inst.C.E. St Stephen's Club, Westminster, S.W.
1914. ‡Grimley, Frank. Wandella, Gale-street, Woolwich, N.S.W.
1911. ‡Grogan, Ewart S. Camp Hill, near Newcastle, Staffs.
1894. ‡GROOM, Professor P., M.A., F.L.S. North Park, Gerrard's Cross, Bucks.
1894. ‡Groom, T. T., M.A., D.Sc., F.G.S., Professor of Geology in the University of Birmingham
1909. **Grossman, Edward L., M.D. Steilacoom, Washington, U.S.A.*
1896. ‡Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1913. ‡Grove, W. B., M.A. 45 Duchess-road, Edgbaston, Birmingham.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. Aberfoyle, Rathgar, Dublin.
1913. §Gruchy, G. F. B. de. Manoir de Noirmont, St. Aubin, Jersey.
1897. ‡Grünbaum, A. S., M.A., M.D. School of Medicine, Leeds.
1910. ‡Grundy, James. Ruislip, Teignmouth-road, Cricklewood, N.W.
1913. ‡Guest, James J. 11 St. Mark's-road, Leamington.
1915. §Guilleband, Claude W. St. John's College, Cambridge.
1887 ‡GUILLEMARD, F. H. H., M.A., M.D. The Mill House, Trumpington, Cambridge.
1905. *Gunn, Donald. Royal Societies Club, St. James's-street, S.W.
1909. ‡Gunne, J. R., M.D. Kenora, Ontario, Canada.
1909. ‡Gunne, W. J., M.D. Kenora, Ontario, Canada.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1904. *Gurney, Sir Eustace. Sprowston Hall, Norwich.
1902 *Gurney, Robert. Ingham Old Hall, Stalham, Norfolk.
1914. §Guthrie, Mrs. Blanche. 184A Ladbroke-grove, W.
1904. ‡Guttmann, Professor Leo F., Ph.D. Queen's University, Kingston, Canada.
1906. *GWYNNE-VAUGHAN, Mrs. HELEN C. I., D.Sc., F.L.S. 14 London-road, Reading.

1905. ‡Hacker, Rev. W. J. Idutywa, Transkei, South Africa.
1908. *Hackett, Felix E. Royal College of Science, Dublin.

Year of Election.

1881. *Haddon, Alfred Cort, M.A , Sc.D., F.R.S., F.Z.S. (Pres. H, 1902, 1905; Council, 1902-08, 1910- .) 3 Cranmer-road, Cambridge.
1914. ‡Haddon, Mrs. 3 Cranmer-road, Cambridge.
1911. *Haddon, Miss Kathleen. 3 Cranmer-road, Cambridge.
1888. *Hadfield, Sir Robert, D.Met., D.Sc., F.R.S., M.Inst.C.E. 22 Carlton House-terrace, S.W.
1913. ‡Hadley, H. E., B.Sc. School of Science, Kidderminster.
1915. §Hadow, W. H., Principal of Armstrong College, Newcastle-on-Tyne.
1905. ‡Hahn, Professor P. H., M.A., Ph.D. York House, Gardens, Cape Town.
1911. ‡Haigh, B. P., B.Sc. James Watt Engineering Laboratory, The University, Glasgow.
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. Cherwell, Oxford.
1909. ‡Hale, W. H., Ph.D. 40 First-place, Brooklyn, New York, U.S.A.
1911. §Halket, Miss A. C. Waverley House, 135 East India-road, E.
1899. ‡Hall, A. D., M.A., F.R.S. (Pres. M, 1914; Council, 1908–15.) Development Commission, 6A Dean's-yard, S.W.
1914. ‡Hall, Mrs. A. D. Ewhurst, Mostyn-road, Merton.
1909. ‡Hall, Archibald A., M.Sc., Ph.D. Armstrong College, Newcastle-on-Tyne.
1914. ‡Hall, Dr. Cuthbert. Glenrowan, Parramatta, Sydney.
1903. ‡Hall, E. Marshall, K.C 75 Cambridge-terrace, W.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. *Hall, Miss Emily. 63 Belmont-street, Southport.
1854. *Hall, Hugh Fergie, F.G.S. Cissbury Court, West Worthing, Sussex.
1884. ‡Hall, Thomas Proctor, M.D. 1301 Davie-street, Vancouver, B.C, Canada.
1908. *Hall, Wilfred, Assoc.M.Inst.C.E. 9 Prior's-terrace, Tynemouth, Northumberland.
1913. ‡Hall-Edwards, J. The Elms, 112 Gough-road, Edgbaston, Birmingham.
1891. *Hallett, George. Oak Cottage, West Malvern.
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, 1911–), 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.
1886. ‡Hambleton, G. W. 109 Ramsden-road, S.W.
1908. *Hamel, Egbert Alexander de. Middleton Hall, Tamworth.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1915. §Hamer, J. St. James'-buildings, Oxford-street, Manchester.
1906. ‡Hamill, John Molyneux, M.A., M.B. 14 South-parade, Chiswick.
1906. ‡*Hamilton, Charles I.* 88 *Twyford-avenue, Acton.*
1909. ‡Hamilton, F. C. Bank of Hamilton-chambers, Winnipeg, Canada.
1902. ‡Hamilton, Rev. T., D.D. Queen's College, Belfast.
1909. ‡Hamilton, T. Glen, M.D. 264 Renton-avenue, Winnipeg, Canada.
1899. *Hanbury, Daniel. Lenqua da Cà, Alassio, Italy.
1878. ‡Hance, E. M. Care of J. Hope Smith, Esq., 3 Leman-street, E C.
1909. ‡Hancock, C. B. Manitoba Government Telephones, Winnipeg, Canada.
1905. *Hancock, Strangman. Kennel Holt, Cranbrook, Kent.
1912. ‡Hankin, G. T. 150 Whitehall-court, S.W.

Year of Election.

1911. ‡Hann, H. F. 139 Victoria-road North, Southsea.
1906. §Hanson, David. Salterlee, Halifax, Yorkshire.
1904. §Hanson, E. K. Woodthorpe, Royston Park-road, Hatch End, Middlesex.
1914. ‡Happell, Mrs. Care of Miss E. M. Bundey, Molesworth Street, North Adelaide, South Australia.
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.
1909. ‡Harcourt, George. Department of Agriculture, Edmonton, Alberta, Canada.
1886. *Hardcastle, Colonel Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1902. *Hardcastle, Miss Frances. 3 Osborne-terrace, Newcastle-on-Tyne.
1903. *Hardcastle, J. Alfred. The Dial House, Crowthorne, Berkshire.
1892. *Harden, Arthur, Ph.D, D.Sc., F.R.S. Lister Institute of Preventive Medicine, Chelsea-gardens, Grosvenor-road, S.W.
1905. ‡*Hardie, Miss Mabel, M.B. High-lane*, via *Stockport.*
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1894. ‡Hardman, S. C. 120 Lord-street, Southport.
1913. ‡Hardy, George Francis. 30 Edwardes-square, Kensington, W.
1909. ‡Hardy, W. B., M.A., F.R.S Gonville and Caius College, Cambridge.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. *Harker, Alfred, M.A., F.R.S., F.G.S. (Pres. C, 1911.) St. John's College, Cambridge.
1914. ‡Harker, Dr. George The University, Sydney, N.S W.
1896. ‡Harker, John Allen, D.Sc., F.R.S. National Physical Laboratory, Bushy House, Teddington.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S , F.S A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
1883. *Harley, Miss Clara. Rastrick, Cricketfield-road, Torquay.
1899. ‡Harman, Dr. N. Bishop, F.R.C.S. 108 Harley-street, W.
1913. ‡Harmar, Mrs. 102 Hagley-road, Birmingham.
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), Keeper of the Department of Zoology, British Museum (Natural History), Cromwell-road, S.W.
1912. *Harper, Alan G., B.A. Magdalen College, Oxford.
1906. ‡Harper, J. B. 16 St. George's-place, York.
1913. ‡Harris, F. W. 132 and 134 Hurst-street, Birmingham.
1842. ‡Harris, G. W. Millicent, South Australia.
1909. ‡Harris, J. W. Civic Offices, Winnipeg.
1903. ‡Harris, Robert, M.B. Queen's-road, Southport.
1904. *Harrison, Frank L., B.A., B.Sc. Grammar School Cottage, St. John's, Antigua, B.W.I.
1904. ‡Harrison, H. Spencer. The Horniman Museum, Forest Hill, S.E.
1892. ‡Harrison, John. (Local Sec. 1892.) Rockville, Napier-road, Edinburgh.
1915 §Harrison, Launcelot. Quick Laboratory, Cambridge.
1892. ‡Harrison, Rev. S. N. Ramsey, Isle of Man.
1901 *Harrison, W. E. 17 Soho-road, Handsworth, Staffordshire.
1911. ‡Harrison-Smith, F., C.B. H.M. Dockyard, Portsmouth.
1885. ‡Hart, Colonel C. J. (Local Sec. 1886.) Highfield Gate, Edgbaston, Birmingham.

Year of Election.

1909. ‡Hart, John A. 120 Emily-street, Winnipeg, Canada.
1876. *Hart, Thomas. Brooklands, Blackburn.
1903. *Hart, Thomas Clifford. Brooklands, Blackburn.
1907. §Hart, W. E. Kilderry, near Londonderry.
1911. ‡Hart-Synnot, Ronald V. O. University College, Reading.
1893. *Hartland, E. Sidney, F.S.A. (Pres. H, 1906; Council, 1906-13.) Highgarth, Gloucester.
1905. ‡Hartland, Miss. Highgarth, Gloucester.
1886. *Hartog, Professor M. M., D.Sc. University College, Cork.
1887. ‡Hartog, P. J., B.Sc. University of London, South Kensington, S.W.
1885. §Harvie-Brown, J. A., LL.D. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1893. §Haslam, Lewis. 8 Wilton-crescent, S.W.
1911. *Hassé, H. R. The University, Manchester.
1903. *Hastie, Miss J. A. Care of Messrs. Street & Co., 30 Cornhill, E.C.
1904. ‡Hastings, G. 23 Oak-lane, Bradford, Yorkshire.
1903. ‡Hastings, W. G. W. 2 Halsey-street, Cadogan-gardens, S.W.
1889. ‡Hatch, F. H., Ph.D., F.G.S. 15 Copse-hill, Wimbledon, S.W.
1903. ‡Hathaway, Herbert G. 45 High-street, Bridgnorth, Salop.
1904. *Haughton, W. T. H. The Highlands, Great Barford, St. Neots.
1908. §Havelock, T. H., M.A., D.Sc., F.R.S., Professor of Applied Mathematics in Armstrong College, Newcastle-on-Tyne. Rockliffe, Gosforth, Newcastle-on-Tyne.
1904. ‡Havilland, Hugh de. Eton College, Windsor.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1864. *Hawkshaw, John Clarke, M.A., M.Inst.C.E., F.G.S. (Council, 1881–87.) 22 Down-street, W.
1897. §Hawksley, Charles, M.Inst.C.E., F.G.S. (Pres. G, 1903; Council, 1902–09.) Caxton House (West Block), Westminster, S.W.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1913. ‡Haworth, John F. Withens, Barker-road, Sutton Coldfield.
1913. ‡Haworth, Mrs. Withens, Barker-road, Sutton Coldfield.
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. 114 Revidge-road, Blackburn.
1913. §Hayward, Miss. 7 Abbotsford-road, Galashiels, N.B.
1903. ‡Hayward, Joseph William, M.Sc. Keldon, St. Marychurch, Torquay.
1896. *Haywood, Colonel A. G. 68 Wharfedale-gardens, Thornton Heath.
1883. ‡Heape, Joseph R. Glebe House, Rochdale.
1882. *Heape, Walter, M.A., F.R.S. 10 King's Bench-walk, Temple, E.C.
1909. ‡Heard, Mrs. Sophie, M.B., Ch.B. Carisbrooke, Fareham, Hants.
1908. §Heath, J. St. George, B.A The Warden's Lodge, Toynbee Hall, Commercial-street, E.
1902. ‡Heath, J. W. Royal Institution, Albemarle-street, W.
1898. ‡Heath, R. S., M.A., D.Sc., Vice-Principal and Professor of Mathematics in the University of Birmingham.
1909. ‡Heathcote, F. C. C. Broadway, Winnipeg, Canada.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1913. §Heaton, Howard. (Local Sec., 1913.) Wayside, Lode-lane, Solihull, Birmingham.
1892. *Heaton, William H., M.A. (Local Sec., 1893), Principal of and 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.

Year of Election.

1888. *Heawood, Percy J., Professor of Mathematics in Durham University. High Close, Hollinside-lane, Durham.
1887. *Hedges, Killingworth, M.Inst.C.E. 10 Cranley-place, South Kensington, S.W.
1912. §Hedley, Charles. Australian Museum, Sydney.
1881. *Hele-Shaw, H. S., D.Sc., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1915.) 64 Victoria-street, S.W.
1901. *Heller, W. M., B.Sc. Education Office, Marlborough-street, Dublin.
1911. ‡Hellyer, Francis E. Farlington House, Havant, Hants.
1911. ‡Hellyer, George E. Farlington House, Havant, Hants.
1887. ‡Hembry, Frederick William, F.R.M.S. City-chambers, 2 St. Nicholas-street, Bristol.
1908. ‡Hemmy, Professor A. S. Government College, Lahore.
1899. ‡Hemsalech, G. A., D.Sc. The Owens College, Manchester.
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 Royal Technical College, Glasgow.
1905. §Henderson, Mrs. 7 Marlborough-drive, Kelvinside, Glasgow.
1907. ‡Henderson, H. F. Felday, Morland-avenue, Leicester.
1906. ‡Henderson, J. B., D.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1909. ‡Henderson, Veylien E. Medical Building, The University, Toronto, Canada.
1880. *Henderson, Admiral W. H., R.N. 3 Onslow Houses, S.W.
1911. ‡Henderson, William Dawson. The University, Bristol.
1904. *Hendrick, James, B.Sc., F.I.C., Professor of Agriculture in Marischal College, Aberdeen.
1910. ‡Heney, T. W. Sydney, New South Wales.
1910. *Henrici, Captain E. O., R.E., A.Inst.C.E. Ordnance Survey Office, Southampton.
1873. *Henrici, Olaus M. F. E., Ph.D., F.R.S. (Pres. A, 1883; Council, 1883–89.) Hiltingbury Lodge, Chandler's Ford, Hants.
1910. ‡*Henry, Hubert, M.D.* 304 *Glossop-road, Sheffield.*
1906. ‡Henry, Dr. T. A. Imperial Institute, S.W.
1909. *Henshall, Robert. Sunnyside, Latchford, Warrington.
1892. ‡Hepburn, David, M.D., F.R.S.E., Professor of Anatomy in University College, Cardiff.
1904. ‡Hepworth, Commander M. W. C., C.B., R.N.R. Meteorological Office, South Kensington, S.W.
1909. ‡Herbinson, William. 376 Ellice-avenue, Winnipeg, Canada.
1914. *Herdman, Miss C Croxteth Lodge, Sefton Park, Liverpool.
1902. ‡Herdman, G. W., B.Sc., Assoc.M.Inst.C.E. Irrigation and Water Supply Department, Pretoria.
1912. *Herdman, George Andrew. Croxteth Lodge, Sefton Park, Liverpool.
1887. *Herdman, William A., D.Sc., LL.D., 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.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.
1909. ‡Herdt, Professor L. A. McGill University, Montreal, Canada.
1875. ‡Hereford, The Right Rev. John Percival, D.D., LL.D., Lord Bishop of. (Pres. L, 1904.) The Palace, Hereford.
1915. §Herford, Miss Caroline. 8 Oak-drive, Fallowfield, Manchester.

Year of Election.

1912. ‡Heron, David, D.Sc. Galton Eugenics Laboratory, University College, W.C.
1912. *Heron-Allen, Edward, F.L.S., F.G.S. 33 Hamilton-terrace, N.W.; and Large Acres, Selsey Bill, Sussex.
1908. *Herring, Percy T., M.D., Professor of Physiology in the University, St. Andrews, N.B.
1874. §Herschel, Colonel John, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1900. *Herschel, Rev. J. C. W. Fircroft, Wellington College Station, Berkshire.
1913. ‡Hersey, Mayo Dyer, A.M. Bureau of Standards, Washington, U.S.A.
1905. ‡Hervey, Miss Mary F. S. 22 Morpeth-mansions, S.W.
1903. *Hesketh, Charles H. Fleetwood, M.A. Stocken Hall, Stretton, Oakham.
1895. §Hesketh, James. 5 Scarisbrick Avenue, Southport.
1913. §Hett, Miss Mary L. 53 Fordwych-road, West Hampstead, N.W.
1894. ‡Hewetson, G. H. (Local Sec. 1896.) 39 Henley-road, Ipswich.
1894. ‡*Hewins, W. A. S., M.A., F.S.S.* 15 *Chartfield-avenue, Putney Hill, S.W.*
1915. §Hewison, William. Winfield, St. George's-crescent, Pendleton.
1908. ‡Hewitt, Dr. C. Gordon. Central Experimental Farm, Ottawa.
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., F.R.S. Clifford House, Staines-road, Bedfont, Middlesex.
1909. ‡Hewitt, W., B.Sc. 16 Clarence-road, Birkenhead.
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.
1912. §Heywood, H. B., D.Sc. 40 Manor-way, Ruislip.
1912. ‡Hickling, George, D.Sc., F.G.S. The University, Manchester.
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; Local Secretary, 1915), Professor of Zoology in Victoria University, Manchester.
1864. *Hiern, W. P., M.A., F.R.S. The Castle, Barnstaple.
1914. ‡Higgins, J. M. Riversdale-road, Camberwell, Victoria.
1914. ‡Higgins, Mrs J. M. Riversdale-road, Camberwell, Victoria.
1891. ‡Higgs, Henry, C.B., LL.B., F.S.S. (Pres. F, 1899; Council, 1904–06.) H.M. Treasury, Whitehall, S.W.
1909. ‡Higman, Ormond. Electrical Standards Laboratory, Ottawa.
1913. *Higson, G. I., M.Sc. 11 Westbourne-road, Birkdale, Lancashire.
1907. ‡Hiley, E. V. (Local Sec. 1907.) Town Hall, Birmingham.
1911. *Hiley, Wilfrid E. Danesfield, Boar's Hill, Oxford.
1885. *Hill, Alexander, M.A., M.D. Hartley University College, Southampton.
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., D.Sc., F.R.S., Professor of Zoology in University College, Gower-street, W.C.

Year of Election.

1911. ‡HILL, LEONARD, M.B., F.R.S. (Pres. I, 1912.) Osborne House, Loughton, Essex.
1912. ‡Hill, M. D. Angelo's, Eton College, Windsor.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1898. *Hill, Thomas Sidney. Langford House, Langford, near Bristol.
1907. *HILLS, Colonel E. H., C.M.G., R.E., F.R.S., F.R.G.S. (Pres. E, 1908.) 32 Prince's-gardens, S.W.
1911. *Hills, William Frederick Waller. 32 Prince's-gardens, S.W.
1903. *Hilton, Harold, D.Sc. 108 Alexandra-road, South 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.
1910. ‡Hindle, Edward, B.A., Ph.D., F.L.S. Quick Laboratories, Cambridge.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1915. *Hindley, R. T. The Green-way, Macclesfield.
1898. ‡Hinds, Henry. 57 Queen-street, Ramsgate.
1911. ‡Hinks, Arthur R., M.A., F.R.S., Sec. R.G.S. Royal Geographical Society, Kensington Gore, S.W.
1903. *Hinmers, Edward. Glentwood, South Downs-drive, Hale, Cheshire.
1915. §Hitchcock, E. F. Toynbee Hall, Commercial-street, E.
1914. ‡Hoadley, C. A., M.Sc. Weenabah, Ballarat, Victoria.
1915. §Hoatson, John. 117 City-road, Edgbaston, Birmingham.
1899. ‡Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1914 ‡Hobson, A. Kyme. Overseas Club, 266 Flinders-street, Melbourne.
1887. *HOBSON, BERNARD, M.Sc., F.G.S. Thornton, Hallamgate-road, Sheffield.
1904. ‡HOBSON, ERNEST WILLIAM, Sc.D., F.R.S. (Pres. A, 1910), Sadlerian Professor of Pure Mathematics in the University of Cambridge. The Gables, Mount Pleasant, Cambridge.
1907. ‡Hobson, Mrs. Mary. 6 Hopefield-avenue, Belfast.
1913. ‡Hodges, Ven. Archdeacon George, M.A. Ely.
1887. *Hodgkinson, Alexander M.B., B.Sc. Bradshaigh, Lower Bourne, near Farnham, Surrey.
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.
1912. ‡Hodgson, Benjamin. The University, Bristol.
1905. ‡Hodgson, Ven. Archdeacon R. The Rectory, Wolverhampton.
1909. ‡Hodgson, R. T., M.A. Collegiate Institute, Brandon, Manitoba, Canada.
1898. ‡Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
1904. *Hodson, F., Ph.D. Bablake School, Coventry.
1907. ‡Hodson, Mrs. Bablake School, Coventry.
1915. §Hoffert, H. H., D.Sc. The Gables, Marple, Stockport.
1904. ‡HOGARTH, D. G., M.A. (Pres. H, 1907; Council, 1907–10.) 20 St. Giles's, Oxford.
1914. ‡Hogben, George, M.A., F.G.S. 9 Tinakori-road, Wellington, New Zealand.
1908. ‡Hogg, Right Hon. Jonathan. Stratford, Rathgar, Co. Dublin.
1911. ‡Holbrook, Colonel A. R. Warleigh, Grove-road South, Southsea.
1907. ‡Holden, Colonel Sir H. C. L., K.C.B., R.A., F.R.S. Gifford House, Blackheath, S.E.
1883. ‡Holden, John J. 73 Albert-road, Southport.
1887. *Holder, Henry William, M.A. Beechmount, Arnside.

Year of Election.

1913. ‡Holder, Sir John C., Bart. Pitmaston, Moor Green, Birmingham.
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., J.P. Fernhill, Alderley Edge, Cheshire.
1904. §Holland, Charles E. 9 Downing-place, Cambridge.
1903. ‡Holland, J. L., B.A. 3 Primrose-hill, Northampton.
1896. ‡Holland, Mrs. Lowfields House, Hooton, Cheshire.
1898. ‡HOLLAND, Sir THOMAS H., K.C.I.E., F.R.S., F.G.S. (Pres. C, 1914), Professor of Geology in the Victoria University, Manchester.
1889. ‡Holländer, Bernard, M.D. 35A Welbeck-street, W.
1906. *Hollingworth, Miss. Leithen, Newnham-road, Bedford.
1883. *Holmes, Mrs. Basil. 23 Corfton-road, Ealing, W.
1866. *Holmes, Charles. Makeney, Compton-road, Winchmore Hill, N.
1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1912. ‡*Holmes-Smith, Edward, B.Sc. Royal Botanic Gardens, Edinburgh.*
1903. *HOLT, ALFRED, M.A., D.Sc. Dowsefield, Allerton, Liverpool.
1915. §HOLT, Alderman E., J.P. Bury Old-road, Heaton Park, Manchester.
1875. *Hood, John. Chesterton, Cirencester.
1904. §Hooke, Rev. D. Burford, D.D. Somerset Lodge, Barnet.
1908. *Hooper, Frank Henry. Deepdene, Streatham Common, S.W.
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.
1913. ‡HOPKINS, F. GOWLAND, M.A., D.Sc., M.B., F.R.S. (Pres. I, 1913). Trinity College, and Saxmeadham, Grange-road, Cambridge.
1901. *HOPKINSON, BERTRAM, M.A., F.R.S., F.R.S.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. 10 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. Weetwood, Watford.
1905. ‡Hopkinson, Mrs. John. Ellerslie, Adams-road, Cambridge.
1898. *Hornby, R., M.A. Haileybury College, Hertford.
1910. ‡Horne, Arthur S. Kerlegh, Cobham, Surrey.
1885. ‡HORNE, JOHN, LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1901.) 12 Keith-crescent, Blackhall, Midlothian.
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.
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.
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.

Year of Election.

1905. §Houghting, A. G. L. Glenelg, Musgrave-road, Durban, Natal.
1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Birmingham.
1914. ‡Houghton, T. H., M.Inst.C.E. 63 Pitt-street, Sydney, N.S.W.
1908. ‡Houston, David, F.L.S. Royal College of Science, Dublin.
1893. ‡Howard, F. T., M.A., F.G.S. West Mount, Waverton, near Chester.
1904. *Howard, Mrs. G. L. C. Agricultural Research Institute, Pusa, Bengal, India.
1887. *Howard, S. S. 56 Albemarle-road, Beckenham, Kent.
1901. §Howarth, E., F.R.A.S. Public Museum, Weston Park, Sheffield.
1903. *Howarth, James H., F.G.S Holly Bank, Halifax.
1907. ‡Howarth, O. J. R., M.A. (Assistant Secretary.) 24 Lansdowne-crescent, W.
1914. ‡Howchin, Professor Walter. University of Adelaide, South Australia.
1911. *Howe, Professor G. W. O., D.Sc. 22 Dorset-road, Merton Park, Surrey.
1905 ‡Howick, Dr. W. P O. Box 503, Johannesburg.
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.) National Museum of Wales, City Hall, Cardiff.
1903. ‡Hübner, Julius. Ash Villa, Cheadle Hulme, Cheshire.
1913. §Huddart, Mrs. J. A. 2 Chatsworth-gardens, Eastbourne.
1898. ‡*Hudson, Mrs. Sunny Bank, Egerton, Huddersfield.*
1913. ‡Hughes, Alfred, M.A., Professor of Education in the University of Birmingham 29 George-road, Edgbaston, Birmingham.
1871. *Hughes, George Pringle, J.P., F.R.G.S. Middleton Hall, Wooler, Northumberland.
1914. ‡Hughes, Herbert W. Adelaide Club, Adelaide, South Australia.
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.
1912. ‡Hukling, George. The University, Manchester.
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. 55 Gladstone-street, Dundee, Natal.
1911. *Hume, Dr. W. F. Helwan, Egypt.
1914. §Humphrey, G. D. Care of Messrs. Lane & Peters, Burrinjuck, New South Wales.
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.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1914. ‡Hunt, H. A. Weather Bureau, Melbourne.
1881. ‡Hunter, F. W. 16 Old Elvet, Durham.
1889. ‡Hunter, Mrs. F. W. 16 Old Elvet, Durham.
1915. §Hunter, W. Henry. 42 Spring-gardens, Manchester.
1909. ‡Hunter, W. J. H. 31 Lynedoch-street, Glasgow.
1901. *Hunter, William. Evirallan, Stirling.
1903. ‡Hurst, Charles C., F.L.S. Burbage, Hinckley.
1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.
1913. §Hutchins, Miss B. L. The Glade, Branch Hill, Hampstead Heath, N.W.
1914. §Hutchins, D. E. Medo House, Cobham, Kent.

Year of Election.

1894. *Hutchinson, A., M.A., Ph.D. (Local Sec. 1904.) Pembroke College, Cambridge.
1912. §Hutchinson, Dr. H. B. Rothamsted Experimental Station, Harpenden, Herts.
1903. §Hutchinson, Rev. H. N., M.A. 17 St. John's Wood Park, Finchley-road, N.W.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1901. *Hutton, R. S., D.Sc. West-street, Sheffield.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman. H. H. Francis. 3 New-court, Lincoln's Inn, W.C.

1908. ‡Idle, George. 43 Dawson-street, Dublin.
1883. ‡Idris, T. H. W. 110 Pratt-street, Camden Town, N.W.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1906. ‡Iliffe, J. W. Oak Tower, Upperthorpe, Sheffield.
1913. §Illing, Vincent Charles, B.A., F.G.S. The Chestnuts, Hartshill, Atherstone, Warwickshire.
1915. §Imms, A. D. West Wood, The Beeches, West Didsbury.
1885. §Im Thurn, Sir Everard F., C.B., K.C.M.G. (Pres. H, 1914; Council, 1913– .) 39 Lexham-gardens, W.
1907. §Ingham, Charles B. Moira House, Eastbourne.
1901. ‡Inglis, John, LL.D. 4 Prince's-terrace, Dowanhill, Glasgow.
1905. §Innes, R. T. A., F.R.A.S. Union Observatory, Johannesburg.
1901. *Ionides, Stephen A. 802 Equitable-building, Denver, Colorado.
1913. ‡Irvine, James, F.R.G.S. Richmond-buildings, Chapel-street, Liverpool.
1912. ‡Irvine, J. C., Ph.D., Professor of Chemistry in the University of St. Andrews.
1882. §Irving, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1908. ‡Irwin, Alderman John. 33 Rutland-square, Dublin.

1915. §Jack, A. J. 30 Amhurst-road, Withington, Manchester.
1914. §Jack, A. K., B.Sc. Agricultural College, Dookie, Victoria.
1909. ‡Jacks, Professor L. P. 28 Holywell, Oxford.
1883. *Jackson, Professor A. H., B.Sc. 349 Collins-street, Melbourne, Australia.
1903. ‡Jackson, C. S. Royal Military Academy, Woolwich, S.E.
1915. §Jackson, E. J. W., B.A. The University, Edmund-street, Birmingham.
1874. *Jackson, Frederick Arthur. Belmont, Somenos, Vancouver Island, B.C., Canada.
1883. *Jackson, F. J. 35 Leyland-road, Southport.
1883. ‡Jackson, Mrs. F. J. 35 Leyland-road, Southport.
1899. ‡Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
1913. *Jackson, H. Gordon, M.Sc. Mason College, Birmingham.
1906. *Jackson, James Thomas, M.A. Engineering School, Trinity College, Dublin.
1898. *Jackson, Sir John. 51 Victoria-street, S.W.
1887. §Jacobson, Nathaniel, J.P. Olive Mount, Cheetham Hill-road, Manchester.
1905. *Jaffé, Arthur, M.A. New-court, Temple, E.C.
1874. *Jaffé, John. Villa Jaffé, 38 Promenade des Anglais, Nice, France.

Year of Election.

1906. ‡Jalland, W. H. Museum-street, York.
1891. *James, Charles Russell. The Bungalow, Redhill, Surrey.
1904. ‡James, Thomas Campbell. University College, Aberystwyth.
1896. *Jameson, H. Lyster, M.A., Ph.D. Borderdale, Sunningdale, Berkshire.
1889. *Japp, F. R., M.A., Ph.D., LL.D., F.R.S. (Pres. B, 1898) 36 Twyford-avenue, West Acton, W.
1910. *Japp, Henry, M.Inst.C.E. 59 Beaver Hall-hill, Montreal, Canada.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1913. ‡Jarrard, W. J. The University, Sheffield.
1903. ‡Jarratt, J. Ernest. (Local Sec. 1903.) 22 Hesketh-road, Southport.
1904. *Jeans, J. H., M.A., F.R.S. 8 Ormonde-gate, Chelsea, S.W.
1897. ‡Jeffrey, E. C., B.A. The University, Toronto, Canada.
1912. §Jehu, T. J., M.A., M.D., Professor of Geology in the University of Edinburgh.
1908. *Jenkin, Arthur Pearse, F.R.Met.Soc. Trewirgie, Redruth.
1909. *Jenkins, Miss Emily Vaughan. 31 Antrim-mansions, South Hampstead, N.W.
1903. ‡Jenkinson, J. W. The Museum, Oxford.
1904. ‡Jenkinson, W. W. 6 Moorgate-street, E.C.
1893. ‡Jennings, G. E. Ashleigh, Ashleigh-road, Leicester.
1900. *Jevons, H. Stanley, M.A., B.Sc. 3 Pembroke-terrace, Cardiff.
1907. *Jevons, Miss H. W. 17 Tredegar-square, Bow, E.
1905. §Jeyes, Miss Gertrude, B.A. Berrymead, 6 Lichfield-road, Kew Gardens.
1914. ‡Jobbins, G. G. Geelong Club, Geelong, Victoria.
1909. *Johns, Cosmo, F.G.S., M.I.M.E. Burngrove, Pitsmoor-road, Sheffield.
1909. ‡*Johnson, C. Kelsall, F.R.G.S. The Glen, Sidmouth, Devon.*
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. Wath Rectory, Melmerby S.O., Yorkshire.
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., F.R.G.S. (Pres. E, 1909.) 8 Lansdowne-crescent, Edinburgh.
1883. ‡Johnston, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. St. John's Priory, Poling, near Arundel.
1913. §Johnston, James. Oak Bank-avenue, Manchester.
1909. *Johnston, J. Weir, M.A. 129 Anglesea-road, Dublin.
1913. ‡Johnston, Dr. S. J. Department of Biology, The University, Sydney, N.S.W.
1908. ‡Johnston, Swift Paine. 1 Hume-street, Dublin.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1909. §Jolly, Professor W. A., M.B., D.Sc. South African College, Cape Town.
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. Eryl Dag, Radyr, Cardiff.
1913. *Jones, Daniel, M.A., Lecturer on Phonetics at University College, London, W.C.
1904. ‡Jones, Miss E. E. Constance. Girton College, Cambridge.
1890. ‡Jones, Rev. Edward, F.G.S. Primrose Cottage, Embsay, Skipton.

Year of Election.

1896. ‡Jones, E. Taylor, D.Sc. University College, Bangor.
1903. ‡Jones, Evan. Ty-Mawr, Aberdare.
1907. *Jones, Mrs. Evan. 39 Hyde Park-gate, S.W.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. 17 Whalley-road, Whalley Range, Manchester.
1891. *Jones, Rev. G. Hartwell, D.D. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge-road, Waterloo, Liverpool.
1912. ‡Jones, J. H. The University, Glasgow.
1913. ‡Jones, O. T., M.A., D.Sc., F.G.S., Professor of Geology in the University College of Wales. Fenton, Caradoc-road, Aberystwyth.
1905. ‡Jones, Miss Parnell. The Rectory, Llanddewi Skyrrid, 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.
1912. §Jones, W. Neilson, M.A. Bedford College, Regent's Park, N.W
1875. **Jose, J. E. Ethersall, Tarbock-road, Huyton, Lancashire.*
1913. ‡Jourdain, Miss Eleanor F. St. Hugh's College, Oxford.
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.
1894. §Julian, Mrs. Forbes. Redholme, Braddon's Hill-road, Torquay.
1914. †Julius, G. A., B.Sc. Culwulla-chambers, 67 Castlereagh-street, Sydney, N.S.W.
1905. §Juritz, Charles F., M.A., D.Sc., F.I.C., Chief of the Division of Chemistry, Union of South Africa. Department of Agriculture, Cape Town.

1888. ‡Kapp, Gisbert, M.Sc., M.Inst.C.E., M.Inst.E.E. (Pres. G, 1913), Professor of Electrical Engineering in the University of Birmingham. 43 Upland-road, Selly Park, Birmingham.
1913. ‡Kay, Henry, F.G.S. 16 Wretham-road, Handsworth, Birmingham.
1915. §Kay, Max M. 82 Daisy Bank-road, Victoria Park, Manchester.
1913. ‡Kaye, G. W. C. Culver, St. James'-avenue, Hampton Hill.
1904. ‡Kayser, Professor H. The University, Bonn, Germany.
1892. ‡Keane, Charles A., Ph.D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
1913. ‡Kebby, Charles H. 75 Sterndale-road, West Kensington Park, W.
1908. ‡Keeble, Frederick, M.A., Sc.D., F.R.S. (Pres. K, 1912), Professor of Botany in University College, Reading.
1913. *Keeling, B. F. E. Survey Department, Giza Branch, Egypt.
1911. *Keith, Arthur, M.D., LL.D., F.R.S., F.R.C.S. Royal College of Surgeons, Lincoln's Inn-fields, W.C.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1908. ‡Kelly, Sir Malachy. Ard Brugh, Dalkey, Co. Dublin.
1908. ‡Kelly, Captain Vincent Joseph. Montrose, Donnybrook, Co. Dublin.
1911. ‡Kelly, Miss. Montrose, Merton-road, Southsea.
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.) Royal Geographical Society, Kensington Gore, S.W.

Year of Election.

1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1898. *Kemp, John T., M.A. 27 Cotham-grove, Bristol.
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.) Athenæum Club, 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.
1913. ‡Kenrick, W. Byng. (Local Sec. 1913.) Metchley House, Somerset-road, Edgbaston, Birmingham.
1893. §Kent, A. F. Stanley, M.A., F.L.S., F.G.S., Professor of Physiology in the University of Bristol.
1901. ‡*Kent, G.* 16 *Premier-road, Nottingham.*
1913. *Kenyon, Joseph, B.Sc., F.I.C. 51 Irving-place, Blackburn.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1915. §Kerfoot, E. H. Springwood Hall, Ashton-under-Lyne.
1915. §Kerfoot, Thomas. Pole Bank Hall, Gee Cross, Cheshire.
1881. ‡Kermode, P. M. C. Claghbene, Ramsey, Isle of Man.
1913. §Kerr, George L. 39 Elmbank-crescent, Glasgow.
1909. ‡Kerr, Hugh L. 68 Admiral-road, Toronto, Canada.
1892. ‡Kerr, J. Graham, M.A., F.R.S., Regius Professor of Zoology in the University of Glasgow.
1889. ‡Kerry, W. H. R. The Sycamores, Windermere.
1910. §Kershaw, J. B. C. West Lancashire Laboratory, Waterloo, Liverpool.
1869 *Kesselmeyer, Charles Augustus. Roseville, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Edelweiss Villa, 19 Broomfield-lane, Hale, Cheshire.
1903. ‡Kewley, James. Balek Papan, Koltei, Dutch Borneo.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1902. ‡*Kidd, George. Greenhaven, Malone Park, Belfast.*
1906. ‡Kidner, Henry, F.G.S. 25 Upper Rock-gardens, Brighton.
1886. §Kidston, Robert, LL.D., F.R.S., F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1901. *Kiep, J. N. 137 West George-street, 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. Canon's House, St. Thomas-street, Southwark, S.E.
1914. ‡Kincaid, Miss Hilda S., D.Sc. Tarana, Kinkora-road, Hawthorn, N.S.W.
1875. *Kinch, Edward, F.I.C. Sunnyside, Chislehurst, Kent.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1914. §King, Miss Georgina Springfield, Darlinghurst, N.S.W.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1883. *King, John Godwin. Stonelands, East Grinstead.
1883. *King, Joseph, M.P. Sandhouse, Witley, Godalming.
1908. §King, Professor L. A. L., M.A. St. Mungo's College Medical School, Glasgow.

Year of Election.

1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.
1912. *King, W. B. R., B.A., F.G.S. Geological Survey, Jermyn-street, S.W.
1912. ‡King, W. J. Harding. 25 York House, Kensington, W.
1870. ‡King, William, M.Inst.C.E. 5 Beach-lawn, Waterloo, Liverpool.
1913. *King, William Wickham, F.G.S. Winds Point, Hagley, near Stourbridge.
1909. ‡Kingdon, A. 197 Yale-avenue, Winnipeg, Canada.
1903. ‡Kingsford, H. S., M.A. 8 Elsworthy-terrace, N.W.
1900. ‡KIPPING, Professor F. STANLEY, D.Sc., Ph.D., F.R.S. (Pres. B, 1908.) University College, Nottingham.
1899. *Kirby, Miss C. F. 8 Windsor-court, Moscow-road, W.
1913. §Kirkaldy, Professor A. W., M.Com. The University, Edmund-street, Birmingham.
1915. *Kitson, A. E. 109 Worple-road, Wimbledon, S.W.
1901. §Kitto, Edward. 2 Great Headland-terrace, Preston, Paignton, South Devon.
1915. §Knecht, E., Ph.D., Professor of Chemistry in the University of Manchester. 131 Sussex-road, Southport.
1914. §Knibbs, G. H., C.M.G., F.R.A.S., F.S S, Commonwealth Statistician. Rialto, Collins-street, Melbourne.
1886. ‡Knight, Captain J. M., F.G.S. Bushwood, Wanstead, Essex.
1912. ‡Knipe, Henry R., F.L.S., F.G.S. 9 Linden-park, Tunbridge Wells.
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. Edgemoor, Burbage, Derbyshire.
1906. *Knowles, Arthur J., B A, M.Inst.C.E. 10 Banbury-road, Wolvercote, Oxford.
1915. *Knowles, Sir Lees, Bart., C.V.O. Westwood, Pendlebury, near Manchester.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1915. §Knox, George. Heol Isaf, Radyr, Glamorgan.
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.
1890. **Krauss, John Samuel, B.A. Stonycroft, Knutsford-road, Wilmslow, Cheshire.*
1888 *Kunz, G. F., M.A., Ph.D., Sc.D. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.

1903. *Lafontaine, Rev. H. C. de. 52 Albert-court, Kensington Gore, S.W.
1909. ‡Laird, Hon. David Indian Commission, Ottawa, Canada.
1904. ‡Lake, Philip. St. John's College, Cambridge.
1904. ‡Lamb, C. G. Ely Villa, Glisson-road, Cambridge.
1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1915. §Lamb, Francis W. Lyndene, High Lane, near Stockport.
1887. ‡LAMB, HORACE, M.A., LL.D., D.Sc., F.R.S. (Pres. A, 1904), Professor of Mathematics in the Victoria University, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1893. *LAMPLUGH, G. W., F.R.S., F.G.S. (Pres. C, 1906.) 13 Beaconsfield-road, St. Albans.
1914. ‡Lane, Charles. Care of John Sanderson & Co., William-street, Melbourne.
1898. *LANG, WILLIAM H., M.B., F.R.S. (Pres. K, 1915), Professor of Cryptogamic Botany in the University of Manchester. 2 Heaton-road, Withington, Manchester.

Year of Election.

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.) 331 Upper Richmond-road, Putney, S.W.
1880. *Lansdell, Rev. Henry, D.D., F.R.A.S., F.R.G.S. Dimsdale, 4 Pond-road, Blackheath Park, London, S.E.
1884. ‡Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1911. ‡Lapthorn, Miss. St. Bernard's, Grove-road South, Southsea.
1885. ‡Lapworth, Charles, LL.D., F.R.S., F.G.S. (Pres. C, 1892.) 38 Calthorpe-road, Edgbaston, Birmingham.
1909. ‡Larard, C.E., Assoc.M.Inst.C.E. 14 Leaside-avenue, Muswell Hill, N.
1887. ‡Larmor, Alexander. Craglands, Helen's Bay, Co. Down.
1881. ‡Larmor, Sir Joseph, M.A., D.Sc., F.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. Headland, Mount Park, Harrow.
1870. *Latham, Baldwin, M.Inst.C.E., F.G.S. Parliament-mansions, Westminster, S.W.
1911. §Lattey, R. T. 243 Woodstock-road, Oxford.
1900. *Lauder, Alexander, D.Sc., Lecturer in Agricultural Chemistry in the Edinburgh and East of Scotland College of Agriculture, Edinburgh.
1911. §Laurie, Miss C. L. 1 Vittoria-walk, Cheltenham.
1913. *Laurie, Mrs. E. B. 11 Marine-parade, Hoylake.
1892. ‡Laurie, Malcolm, B.A., D.Sc., F.L.S. School of Medicine, Surgeons' Hall, Edinburgh.
1907. *Laurie, Robert Douglas, M.A. Department of Zoology, The University, Liverpool.
1870. *Law, Channell. Ilsham Dene, Torquay.
1914. §Lawrence, A. H. Urunga, N.S.W.
1905. ‡Lawrence, Miss M. Roedean School, near Brighton.
1911. *Lawson, A. Anstruther, D.Sc., F.R.S.E., F.L.S., Professor of Botany in the University, Sydney, N.S.W.
1908. ‡Lawson, H. S., B.A. Buxton College, Derbyshire.
1908. ‡Lawson, William, LL.D. 27 Upper Fitzwilliam-street, Dublin.
1914. ‡Layard, J. W. Bull Cliff, Felixstowe.
1888. ‡Layard, Miss Nina F., F.L.S. Rookwood, Fonnereau-road, Ipswich.
1913. §Lea, F. C., D.Sc. 36 Mayfield-road, Moseley, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1914. ‡Leach, T. H. de Blois. Yardley Lodge, Crick-road, Oxford.
1894. *Leahy, A. H., M.A., Professor of Mathematics in the University of Sheffield. 92 Ashdell-road, Sheffield.
1905. ‡Leake, E. O. 5 Harrison-street, Johannesburg.
1901. *Lean, George, B.Sc. 3 Park-quadrant, 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., D.Sc., Professor of Geology in the Armstrong College of Science, Newcastle-on-Tyne.
1910. ‡Lebour, Miss M. V., M.Sc. Zoological Department, The University, Leeds.
1912. ‡Lechmere, A. Eckley, M.Sc. Townhope, Hereford.
1895. *Ledger, Rev. Edmund. Protea, Doods-road, Reigate.
1914. ‡Lee, Charles Alfred. Tenterfield, N.S.W.

Year of Election.

1910. **Lee, Ernest. Birkbeck College, Chancery-lane, E.C.*
1896. §Lee, Rev. H. J. Barton. 126 Mile End-lane, Stockport.
1907. ‡Lee, Mrs. Barton. 126 Mile End-lane, Stockport.
1909. §Lee, I. L. 26 Broadway, New York City, U.S.A.
1909. ‡Lee, Rev. J. W., D.D. 5068 Washington-avenue, St. Louis, Missouri, U.S.A.
1894. *Lee, Mrs. W. The Nook, Forest Row, Sussex.
1909. ‡Leeming, J. H., M.D. 406 Devon-court, Winnipeg, Canada.
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, Woodside-road, Woodford Green, Essex.
1915. §Lees, Mrs. H. L., F.R.G.S. Leesdene, Hale, Altrincham.
1912. ‡Lees, John. Pitscottie, Cupar-Fife, N.B.
1886. *Lees, Lawrence W. Lynstone, Barnt Green.
1906. ‡Lees, Robert. Victoria-street, Fraserburgh.
1915. §Lees, S. School of Technology, Manchester.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1906. ‡Leetham, Sidney. Elm Bank, York.
1912. ‡Leggat, W. G. Bank of Scotland, Dundee.
1912. ‡Legge, James G. Municipal Buildings, Liverpool.
1910. §Leigh, H. S. Brentwood, Worsley, near Manchester.
1915. §Leigh, T. B. Arden, Bredbury, near Stockport.
1891. ‡Leigh, W. W. Glyn Bargoed, Treharris, R.S.O., Glamorganshire.
1903. ‡Leighton, G. R., M.D., F.R.S.E. Local Government Board, 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.
1913. ‡Leith, Professor R. F. C., M.A., M.Sc. Pathological Laboratory, The University, Birmingham.
1903. *Lempfert, R. G. K., M.A. 66 Sydney-street, S.W.
1908. ‡Lentaigne, John. 42 Merrion-square, Dublin.
1887. *Leon, John T., M.D., B.Sc. 23 Grove-road, Southsea.
1901. §Leonard, J. H., B.Sc. 31 Gunterstone-road, West Kensington, W.
1915. §Leslie, Miss M. S. 1 Park View-terrace, Halton, near Leeds.
1914. ‡Le Souef, W. H. D., C.M.Z.S. Zoological Gardens, Parkville, Victoria.
1913. ‡Lessing, R., Ph.D. 317 High Holborn, W.C.
1912. *Lessner, C., F.C.S. Carril, Spain.
1890. *Lester, Joseph Henry. 5 Grange-drive, Monton Green, 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 University, Belfast.
1896. ‡Lever, Sir W. H., Bart. Thornton Manor, Thornton Hough, Cheshire.
1913. ‡Levick, John. Livingstone House, Livingstone-road, Handsworth, Birmingham.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
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.
1913. ‡Lewis, E. O. Gwynfa, Alma-street, Brynmawr.

Year of Election.

1899. ‡Lewis, Professor E. P. University of California, Berkeley, U.S.A.
1910. ‡Lewis, Francis J., D.Sc., F.L.S., Professor of Biology in the University of Alberta, Edmonton, Alberta, Canada.
1904. ‡Lewis, Hugh. Glanafrau, Newtown, Montgomeryshire.
1910. *Lewis, T. C. West Home, West-road, Cambridge.
1911. §Lewis, W. C. McC., M.A., D.Sc., Professor of Physical Chemistry in the University of Liverpool.
1906. ‡Liddiard, James Edward, F.R.G.S. Rodborough Grange, Bournemouth.
1913. *Lillie, D. G. St. John's College, Cambridge.
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.
1913. *Lishman, G. P., D.Sc., F.I.C. Chemical Laboratory, Lambton Coke Works, Fence Houses, Co. Durham.
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. Fieldhead, George-road, Kingston Hill, Surrey.
1902. §Llewellyn, Evan. Working Men's Institute and Hall, Blaenavon.
1912. §Lloyd, Miss Dorothy Jordan. 16 Ampton-road, Edgbaston, Birmingham.
1909. §Lloyd, George C., Secretary of the Iron and Steel Institute. 28 Victoria-street, S.W.
1903 ‡Lloyd, Godfrey I. H. The University of Toronto, Canada.
1892. ‡Loch, Sir 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.
1914. ‡Lockyer, Ormonde H. S. 126 Webster-street, Ballarat, Victoria.
1900. §Lockyer, W. J. S., Ph.D. 16 Penywern-road, S.W.
1886. *Lodge, Alfred, M.A. (Council, 1913–15.) The Croft, Peperharow-road, Godalming.
1914 ‡Lodge, Miss Lorna L. Mariemont, Edgbaston, Birmingham.
1914. ‡Lodge, Miss Norah M. Mariemont, Edgbaston, Birmingham.
1875. *Lodge, Sir Oliver J., D.Sc., LL.D., F.R.S. (President, 1913; Pres. A, 1891; Council, 1891–97, 1899–1903, 1912–13), Principal of the University of Birmingham.
1914. ‡Lodge, Lady. Mariemont, Edgbaston, Birmingham.
1894. *Lodge, Oliver W. F. Mariemont, Edgbaston, Birmingham.
1915. §Lomas, L. H. Beech Hall, Tytherington, near Macclesfield.
1915. §Lomax, James, A.L.S. 65 Starcliffe-street, Great Lever, Bolton.
1899. ‡Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1903. ‡Long, Frederick. The Close, Norwich.
1905. ‡Long, W. F. City Engineer's Office, Cape Town.
1910. *Longden, G. A. Draycott Lodge, Derby.
1904. *Longden, J. A., M.Inst.C.E. Chislehurst, Marlborough-road, Bournemouth.
1898. *Longfield, Miss Gertrude. Belmont, High Halstow, Rochester.
1901. *Longstaff, Captain Frederick V., F.R.G.S. No. 1252 Post Office, Victoria, B.C., Canada.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.

Year of Election.

1872. *Longstaff, Lieut.-Colonel 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. Picket Hill, Ringwood.
1903. ‡*Loton, John, M.A.* 23 *Hawkshead-street, Southport.*
1897. ‡Loudon, James, LL.D., President of the University of Toronto, Canada.
1896. ‡Louis, Henry, D.Sc., Professor of Mining in the Armstrong 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., D.Sc. The University, Melbourne, Australia
1904. *Love, J. B., LL.D. Outlands, Devonport.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1908. §Low, Alexander, M.A., M.D. The University, Aberdeen.
1909. ‡Low, David, M.D. 1927 Scarth-street, Regina, Saskatchewan, Canada.
1912. ‡Low, William. Balmakewan, Seaview, Monifieth.
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.
1886. *Lowe, John Landor, B.Sc., M.Inst.C.E. Welland Lodge, Prestbury-road, Cheltenham.
1894. ‡Lowenthal, Miss Nellie. Woodside, Egerton, Huddersfield.
1903. *Lowry, Dr. T. Martin, F.R.S. 17 Eliot-park, Lewisham, S.E.
1913. §Lucas, Sir Charles P., K.C.B., K.C.M.G. (Pres. E, 1914.) 65 St. George's-square, S.W.
1913. §Lucas, Harry. Hilver, St. Agnes-road, Moseley, Birmingham.
1901. *Lucas, Keith, Sc.D., F.R.S. Trinity College, Cambridge.
1891. *Lucovich, Count A. Tyn-y-parc, Whitchurch, near Cardiff.
1906. ‡Ludlam, Ernest Bowman College Gate, 32 College-road, Clifton, Bristol.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S. 7 Victoria-street, S.W.
1914. §Lupton, Mrs. 7 Victoria-street, S.W.
1874. *Lupton, Sydney, M.A. (Local Sec. 1890.) 102 Park-street, Grosvenor-square, W.
1915. §Lusgarten, J. School of Technology, Manchester.
1898 ‡Luxmoore, Dr. C. M., F.I.C. 19 Disraeli-gardens, Putney, S.W.
1903 ‡Lyddon. Ernest H. Lisvane, near Cardiff.
1871. ‡Lyell, Sir Leonard, Bart., F.G.S. Kinnordy, Kirriemuir.
1914. ‡Lyle, Professor T. R., M.A., F.R.S. Irving-road, Toorak, Victoria, Australia.
1884 ‡Lyman, H. H. 384 St Paul-street, Montreal, Canada.
1912. *Lynch, Arthur, M.A., M.P. 80 Antrim-mansions, Haverstock Hill, N.W.
1907. *Lyons, Major Henry George, D.Sc., F.R.S. (Pres. E, 1915; Council, 1912–15.) 3 Durham-place, Chelsea, S.W.
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.

Year of Election.

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.
1896. ‡Macallum, Professor A. B., Ph.D., D.Sc., F.R.S. (Pres. I, 1910; Local Sec. 1897.) 59 St. George-street, Toronto, Canada.
1914. ‡McAlpine, D. Berkeley-street, Hawthorn, Victoria.
1915. §Macalpine, Sir George W. Broad Oak, Accrington.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. ‡MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1915. §Macara, Sir C. W. Ardmore, St. Anne's-on-Sea.
1909. ‡MacArthur, J. A., M.D. Canada Life-building, Winnipeg, Canada.
1896. *Macaulay, F. S., M.A. The Chesters, Vicarage-road, East Sheen, S.W.
1904. *Macaulay, W. H. King's College, Cambridge.
1896. ‡MacBride, E. W., M.A., D.Sc., F.R.S., Professor of Zoology in the Imperial College of Science and Technology, S.W.
1902. *Maccall, W. T., M.Sc. Technical College, Sunderland.
1912. ‡McCallum, George Fisher. 142 St. Vincent-street, Glasgow.
1912. ‡McCallum, Mrs. Lizzie. 142 St. Vincent-street, Glasgow.
1886. ‡MacCarthy, Rev. E. F. M., M.A 50 Harborne-road, Edgbaston, Birmingham.
1908. §McCarthy, Edward Valentine, J.P. Ardmanagh House, Glenbrook, Co. Cork.
1909. ‡McCarthy, J. H. Public Library, Winnipeg, Canada.
1884. *McCarthy, J. J., M.D. 11 Wellington-road, Dublin.
1904. §McClean, Frank Kennedy. Rusthall House, Tunbridge Wells.
1902. ‡McClelland, J. A., M.A., F.R.S., Professor of Physics in University College, Dublin.
1906. ‡McClure, Rev. E. 80 Eccleston-square, S.W.
1914. ‡McColl, Miss Ada. Post Office, Parkville, Victoria.
1878. *M'Comas, Henry. 12 Elgin-road, Dublin.
1908. *McCombie, Hamilton, M.A., Ph.D. The University, Birmingham.
1914. *McCombie, Mrs. Hamilton. The University, Birmingham.
1901. *MacConkey, Alfred. Lister Lodge, Elstree, Herts.
1915. §McConnel, John W. Wellbank, Prestwich.
1901. ‡McCrae, John, Ph.D. 7 Kirklee-gardens, Glasgow.
1912. ‡MacCulloch, Rev. Canon J. A., D.D. The Rectory, Bridge of Allan.
1905. §McCulloch, Principal J. D. Free College, Edinburgh.
1904. ‡McCulloch, Major T., R.A. 68 Victoria-street, S.W.
1915. §McDonald, Dr. Archie W. Glencoe, Huyton, Liverpool.
1909. ‡MacDonald, Miss Eleanor. Fort Qu'Appelle, Saskatchewan, Canada.
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.
1905. ‡Macdonald, J. S., B.A. (Pres. I, 1911), Professor of Physiology in the University of Sheffield.
1884. *Macdonald, Sir W. C. 449 Sherbrooke-street West, Montreal, Canada.
1909. ‡MacDonell, John, M.D. Portage-avenue, Winnipeg, Canada.
1909. *MacDougall, R. Stewart. The University, Edinburgh.
1915. *McDougall, Robert, B.Sc. Lerryn, Carr Wood-road, Cheadle Hulme, Stockport.
1912. ‡McDougall, Dr. W., F.R.S. Woodsend, Foxcombe Hill, near Oxford.
1906. §McFarlane, John, M.A. 48 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.

Year of Election.

1901. ‡Macfee, John. 5 Greenlaw-terrace, Paisley.
1909. ‡Macgachen, A. F. D. 281 River-avenue, Winnipeg, Canada.
1888. ‡*MacGeorge, James.* 8 *Matheson-road, Kensington, W.*
1908. ‡McGrath, Sir Joseph, LL.D. (Local Sec. 1908.) Royal University of Ireland, Dublin.
1908. ‡McGregor, Charles. Training Centre, Charlotte-street, Aberdeen.
1906. ‡Macgregor, D. H., M.A. Trinity College, Cambridge.
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.
1909. ‡McIntyre, Alexander. 142 Maryland-avenue, Winnipeg, Canada.
1909. ‡McIntyre, Daniel. School Board Offices, Winnipeg, Canada.
1912. ‡McIntyre, J. Lewis, M.A., D.Sc. Abbotsville, Cults, Aberdeenshire.
1909. ‡McIntyre, W. A. 339 Kennedy-street, Winnipeg, Canada.
1884. §MacKay, A. H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1913. *Mackay, John. 85 Bay-street, Toronto, Canada.
1915. §Mackay, John. 46 Acomb-street, Manchester.
1885. ‡Mackay, John Yule, M.D., LL.D., Principal of and Professor of Anatomy in University College, Dundee.
1912. ‡Mackay, R. J. 27 Arkwright-road, Hampstead, N.W.
1908. ‡McKay, William, J.P. Clifford-chambers, York.
1909. §McKee, Dr. E. S. 2132 Sinton-avenue, W.H., Cincinnati, U.S.A.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E. (Pres. I, 1901; Council, 1903–09), Emeritus Professor of Physiology in the University of Glasgow. Maxieburn, Stonehaven, N.B.
1909. ‡McKenty, D. E. 104 Colony-street, Winnipeg, Canada.
1907. ‡McKenzie, Alexander, M.A., D.Sc., Ph.D. Birkbeck College, Chancery-lane, W.C.
1905. ‡Mackenzie, Hector. Standard Bank of South Africa, Cape Town.
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1910. ‡Mackenzie, K. J. J., M.A. 10 Richmond-road, Cambridge.
1909. ‡MacKenzie, Kenneth. Royal Alexandra Hotel, Winnipeg, Canada.
1901. *Mackenzie, Thomas Brown. Netherby, Manse-road, Motherwell, N.B.
1912. §Mackenzie, William, J.P. 22 Meadowside, Dundee.
1872. *Mackey, J. A. United University Club, Pall Mall East, S.W.
1901. ‡Mackie, William, M.D. 13 North-street, Elgin.
1887. ‡Mackinder, H. J., M.A., M.P., F.R.G.S. (Pres. E, 1895; Council, 1904–05.) 10 Chelsea-court, Chelsea Embankment, S.W.
1911. ‡Mackinnon, Miss D. L. University College, Dundee.
1915. §McLardy, Samuel. Basford Mount, Higher Crumpsall.
1893. *McLaren, Mrs. E. L. Colby, M.B., Ch.B. 137 Tettenhall-road, Wolverhampton.
1901. *Maclaren, J. Malcolm. Royal Colonial Institute, Northumberland-avenue, W.C.
1913. ‡McLaren, Professor S. B., M.A. University College, Reading.
1901. ‡Maclay, William. Thornwood, Langside, Glasgow.
1901. ‡McLean, Angus, B.Sc. Harvale, Meikleriggs, Paisley.
1892. *Maclean, Magnus, M.A., D.Sc., F.R.S.E. (Local Sec. 1901), Professor of Electrical Engineering, Technical College, Glasgow.
1912. §McLean, R. C., B.Sc. Duart, Holmes-road, Reading.
1908. §McLennan, J. C., Professor of Physics in the University of Toronto, Canada.
1868. §McLeod, Herbert, LL.D., F.R.S. (Pres. B, 1892; Council, 1885–90.) 37 Montague-road, Richmond, Surrey.

Year of Election.

1909. ‡MacLeod, M. H. C.N.R. Depôt, Winnipeg, Canada.
1883. ‡MacMahon, Major Percy A., D.Sc., LL.D., F.R.S. (Trustee, 1913– ; General Secretary, 1902–13 ; Pres. A, 1901 ; Council, 1898–1902.) 27 Evelyn-mansions, Carlisle-place, S.W.
1909. ‡McMillan, The Hon. Sir Daniel H., K.C.M.G. Government House, Winnipeg, Canada.
1902. ‡McMordie, Robert J. Cabin Hill, Knock, Co. Down.
1914. §Macnab, Angus D. Oakbank, Tullamarine, Victoria, Australia
1914. ‡Macnicol, A. N. 31 Queen-street, Melbourne
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1905. §Macphail, Dr. S. Rutherford. Rowditch, Derby.
1909. ‡MacPhail, W. M. P.O. Box 88, Winnipeg, Canada.
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, Professor E. J., M.D. 84 St. Stephen's-green, Dublin.
1910. ‡McWilliam, Dr. Andrew. Kalimate, B.N.R., near Calcutta.
1908. ‡Madden, Rt. Hon. Mr. Justice. Nutley, Booterstown, Dublin.
1905. ‡Magenis, Lady Louisa. 34 Lennox-gardens, S.W.
1909. ‡Magnus, Laurie, M.A. 12 Westbourne-terrace, W.
1875. *Magnus, Sir Philip, B.Sc., B.A., M.P. (Pres. L, 1907.) 16 Gloucester-terrace, Hyde Park, W.
1908. *Magson, Egbert H. Westminster College, Horseferry-road, S.W.
1907. *Mair, David. Civil Service Commission, Burlington-gardens, W.
1902. *Mairet, Mrs. Ethel M. The Thatched House, Shottery, Stratford-on-Avon.
1914. ‡Maitland, A Gibb. Geological Survey, Perth, Western Australia.
1913. ‡Maitland, T. Gwynne, M.D. The University, Edmund-street, Birmingham.
1908. *Makower, W., M.A., D.Sc. The University, Manchester.
1914. ‡Malinowski, B. London School of Economics, Clare Market, W.C.
1912. ‡Malloch, James, M.A., F.S.A. (Scot.). Training College, Dundee.
1905. ‡Maltby, Lieutenant G. R., R.N. 54 St. George's-square, S.W.
1897. ‡*Mance, Sir H. C. Old Woodbury, Sandy, Bedfordshire.*
1915. §Mandleberg, G. C. Redclyffe, Victoria Park, Manchester.
1903. ‡Manifold, C. C. 16 St. James's-square, S.W.
1894. ‡Manning, Percy, M.A., F.S.A. Watford, Herts.
1915. §Manson, John Sinclair, M.D. 8 Winmarleigh-street, Warrington.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1902. *Marchant, E. W., D.Sc., David Jardine Professor of Electrical Engineering in the University of Liverpool.
1912. ‡Marchant, Rev. James, F.R.S.E. 42 Great Russell-street, W.C.
1898. *Mardon, Heber. Cliffden, Teignmouth, South Devon.
1911. *Marett, R. R , D Sc. Exeter College, Oxford
1900. ‡Margerison, Samuel. Calverley Lodge, near Leeds.
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, 1910–14.) 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.

Year of Election

1883. *Marsh, Henry Carpenter. 3 Lower James-street, Golden-square, W
1887. ‡Marsh, J. E., M.A., F.R.S. University Museum, Oxford.
1915. §Marsh, J. H., M.D. Cumberland House, Macclesfield.
1889. *Marshall, Alfred, M.A., LL.D., D.Sc. (Pres. F, 1890.) Balliol Croft, Madingley-road, Cambridge.
1912. ‡Marshall, Professor C. R., M.A., M.D. The Medical School, Dundee.
1904. ‡Marshall, F. H. A. University of Edinburgh.
1905. ‡Marshall, G. A. K. 6 Chester-place, Hyde Park-square, W.
1907. ‡Marston, Robert. 14 Ashleigh-road, Leicester.
1899. ‡Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.
1911. ‡Martin, Professor Charles James, M.B., D.Sc., F.R.S., Director of the Lister Institute, Chelsea-gardens, S.W.
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. Windermere, Mount Pleasant-road, Hastings.
1912. ‡Martin, W. H. Blyth. (Local Sec. 1912.) City Chambers, Dundee.
1911. §Martindell, E. W., M.A. Royal Anthropological Institute, 50 Great Russell-street, W.C.
1913. ‡Martineau, Lieut.-Colonel Ernest, V.D. Ellerslie, Augustus-road, Edgbaston, Birmingham.
1913. §Martineau, P. E. The White House, Wake Green-road, Moseley, Birmingham.
1907. ‡Masefield, J. R. B., M.A. Rosehill, Cheadle, Staffordshire.
1905. *Mason, Justice A. W. Supreme Court, Pretoria.
1913. *Mason, Edmund W., B.A. 2 York-road, Edgbaston, Birmingham.
1893. *Mason, Thomas. Enderleigh, Alexandra Park, Nottingham.
1915. *Mason, Rev. W. A. Parker. Hulme Grammar School, Alexandra Park, Manchester.
1913. ‡Mason, William. Engineering Laboratory, The University, Liverpool.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, David Orme. D.Sc., F.R.S., Professor of Chemistry in the University of Melbourne.
1910 ‡Masson, Irvine, M.Sc. University College, W.C.
1905. §Massy, Miss Mary. 2 Duke-street, Bath.
1901. *Mather, G. R. Sunnyville, Park-crescent, Wellingborough.
1910. *Mather, Thomas, F.R.S., Professor of Electrical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W.
1887. *Mather, Right Hon. Sir William, M.Inst.C.E. Salford Iron Works, Manchester.
1909. ‡Mathers, Mr. Justice. 16 Edmonton-street, Winnipeg, Canada.
1913. ‡Matheson, Miss M. Cecile. Birmingham Women's Settlement, 318 Summer-lane, Birmingham.
1908. ‡Matheson, Sir R. E., LL.D. Charlemont House, Rutland-square, Dublin.
1894. ‡Mathews, G. B., M.A., F.R.S. 10 Menai View, Bangor, North Wales.
1902. ‡Matley, C. A., D.Sc. Military Accounts Department, Naina Tal, U.P., India.
1904 ‡Matthews, D. J. The Laboratory, Citadel Hill, Plymouth.
1899. *Maufe, Herbert B., B.A., F.G.S. P.O. Box 168, Bulawayo, Rhodesia.

Year of Election.

1914. ‡Maughan, M. M., B.A., Director of Education. Parkside, South Australia.
1893. ‡Mavor, Professor James. University of Toronto, Canada.
1894. §Maxim, Sir Hiram S. Thurlow Park, Norwood-road, West Norwood, S.E.
1905. *Maylard, A. Ernest. 12 Blythswood-square, Glasgow.
1905. ‡Maylard, Mrs. 12 Blythswood-square, Glasgow.
1878. *Mayne, Thomas. 19 Lord Edward-street, Dublin.
1904. ‡Mayo, Rev. J., LL.D. 6 Warkworth-terrace, Cambridge.
1912. §Meek, Alexander, M.Sc., Professor of Zoology in the Armstrong College of Science, Newcastle-on-Tyne.
1913. §Megson, A. L. Cambridge-street, Manchester.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1905. ‡Mein, W. W. P.O. Box 1145, Johannesburg.
1908. ‡*Meldrum, A. N., D.Sc. Chemical Department, The University, Manchester.*
1915. §Melland, W. 23 King-street, Manchester.
1883. ‡Mellis, Rev. James. 23 Part-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1881. §Melrose, James. Clifton Croft, York.
1905. *Melvill, E. H. V., F.G.S., F.R.G.S. P.O. Val, Standerton District, Transvaal.
1901. ‡Mennell, F. P., F.G.S. 49 London Wall, E.C.
1913. *Mentz-Tolley, Richard. Moseley Court, near Wolverhampton.
1909. ‡Menzies, Rev. James, M.D. Hwaichingfu, Honan, China.
1914. §Meredith, Mrs. C. M. 55 Bryansburn-road, Bangor, Co. Down.
1905. ‡Meredith, H. O., M.A., Professor of Economics in Queen's University, Belfast. 55 Bryansburn-road, Bangor, Co. Down.
1879. ‡Merivale, John Herman, M.A. (Local Sec. 1889.) Togston Hall, Acklington.
1899. *Merrett, William H., F.I.C. Hatherley, Grosvenor-road, Wallington, Surrey.
1899. ‡Merryweather, J. C. 4 Whitehall-court, S.W.
1915. §Merton, Thomas R. 25 Gilbert-street, W.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1914. §Messent, A. E. The Observatory, Adelaide, South Australia.
1905. ‡Methven, Cathcart W. Club Arcade, Smith-street, Durban.
1896. §Metzler, W. H., Ph.D., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1915. §Meunier, Stanislas. Gas Works, Stockport.
1915. §Meunier, Mrs. 16 Gibson-road, Heaton Chapel, Stockport.
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. *Micklethwait, Miss Frances M. G. 15 St. Mary's-square, Paddington, W.
1912. §Middlemore, Thomas, B.A. Melsetter, Orkney.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Bishop's House, Middlesbrough.
1904. ‡Middleton, T. H., C.B., M.A. (Pres. M, 1912.) Board of Agriculture and Fisheries, 4 Whitehall-place, S.W.
1894. *Miers, Sir Henry A., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1905; Pres. L, 1910), Vice-Chancellor of the University of Manchester. Birch Heys, Cromwell Range, Fallowfield, Manchester.
1885. ‡Mill, Hugh Robert, D.Sc., LL.D., F.R.S.E., F.R.G.S (Pres. E, 1901.) 62 Camden-square, N.W.

Year of Election.

1905. ‡Mill, Mrs. H. R. 62 Camden-square, N.W.
1912. ‡Millar, Dr. A. H. (Local Sec. 1912.) Albert Institute, Dundee.
1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
1909. §Miller, A. P. Glen Miller, Ontario, Canada.
1915. §Miller, Dr. Alexander K. 4 Darley-avenue, West Didsbury.
1895 ‡Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1897. *Miller, Willet G., Provincial Geologist. Provincial Geologist's Office, Toronto, Canada.
1904. ‡Millis, C. T. Hollydene, Wimbledon Park-road, Wimbledon.
1905. ‡Mills, Mrs. A. A. Ceylon Villa, Blinco-grove, 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, 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.
1910. §Milne, J. B. Cross Grove House, Totley, near Sheffield.
1910. *Milne, James Robert, D.Sc., F.R.S.E. 5 North Charlotte-street, Edinburgh.
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 University, Belfast.
1907. §Milton, J. H., F.G.S., F.L.S., F.R.G.S. 8 College-avenue, Crosby, Liverpool.
1914. ‡Minchin, Mrs. 53 Cheyne-court, Chelsea, S.W.
1901. *Mitchell, Andrew Acworth. 7 Huntly-gardens, Glasgow.
1913. *Mitchell, Francis W. V. 25 Augustus-road, Edgbaston, Birmingham.
1901. *Mitchell, G. A. 5 West Regent-street, Glasgow.
1909. ‡Mitchell, J. F. 211 Rupert-street, Winnipeg, Canada.
1885. ‡Mitchell, P. Chalmers, M.A., D.Sc., F.R.S., Sec.Z.S. (Pres. D, 1912; Council, 1906–13.) Zoological Society, Regent's Park, N.W.
1905. *Mitchell, W. E. C. Box 129, Johannesburg.
1908. ‡Mitchell, W M. 2 St. Stephen's Green, Dublin.
1914. ‡Mitchell, William, M.A, D.Sc, Hughes Professor of Philosophy and Economics in the University of Adelaide, South Australia.
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. §Molengraaff, Professor G. A. F. Voorstraat 60, Delft, The Hague.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1900. *Monckton, H. W., Treas. L.S., F.G.S. 3 Harcourt-buildings, Temple, E.C.
1905. *Moncrieff, Colonel Sir C. Scott, G.C.S.I., K.C.M.G., R.E. (Pres. G, 1905.) 11 Cheyne-walk, S.W.
1905. ‡Moncrieff, Lady Scott. 11 Cheyne-walk, S.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. Combe Bank, Sevenoaks.
1915. §Moodie, J. Williams Deacon's Bank, Manchester.
1909. ‡Moody, A. W., M.D. 432½ Main-street, Winnipeg, Canada.
1909. *Moody, G. T., D.Sc. Lorne House, Dulwich, S.E.

Year of Election.

1914. §Moody, Mrs. Lorne House, Dulwich, S.E.
1912. §Moore, Benjamin, D.Sc., F.R.S. (Pres. 1, 1914.) 8 Pembroke-villas, The Green, Richmond, Surrey.
1911. §Moore, E. S., Professor of Geology and Mineralogy in the School of Mines, Pennsylvania State College, Pennsylvania, U.S.A.
1908. *Moore, Sir 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.
1892. ‡Moray, The Right Hon. the Earl of, F.G.S. Kinfauns Castle, Perth.
1912. ‡Moray, The Countess of. Kinfauns Castle, Perth.
1896. *Mordey, W. M. 82 Victoria-street, S.W.
1901. *Moreno, Francisco P. Paraná 915, Buenos Aires.
1905. ‡Morgan, Miss Annie. Care of London County and Westminster Bank, Chancery-lane, W.C.
1895. ‡Morgan, C. Lloyd, F.R.S., F.G.S., Professor of Psychology in the University of Bristol.
1902. ‡Morgan, Gilbert T., D.Sc., F.I.C., Professor of Chemistry in the Royal College of Science, Dublin.
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, Dr. R. S. Tor Lodge, Tettenhall Wood, Wolverhampton.
1892. ‡Morris, Sir Daniel, K.C.M.G., D.Sc., F.L.S. (Council, 1915– .) 14 Crabton-close, Boscombe, Hants.
1915. *Morris, H. N. Gorton Brook Chemical Works, Manchester.
1896. *Morris, J. T. 36 Cumberland-mansions, Seymour-place, W.
1880. §Morris, James. 23 Brynymor-crescent, 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.
1909. ‡Morse, Morton F. Wellington-crescent, Winnipeg, Canada.
1886. *Morton, P. F. 15 Ashley-place, Westminster, S.W.
1896. *Morton, William B., M.A., Professor of Natural Philosophy in Queen's University, Belfast.
1913. §Mosely, Alfred. West Lodge, Barnet.
1908. ‡Moss, C. E., D.Sc. Botany School, Cambridge.
1912. ‡Moss, Mrs. 154 Chesterton-road, 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. Health Office, Houndgate, Darlington.
1913. ‡Mott, Dr. F. W., F.R.S. 25 Nottingham-place, W.
1913. ‡Mottram, V. H. 256 Lordship-lane, East Dulwich, S.E.
1912. *Moulton, J. C. Sarawak Museum, Sarawak.
1878. *Moulton, The Right Hon. Lord Justice, K.C.B., M.A., K.C., F.R.S. 57 Onslow-square, S.W.
1899 ‡Mowll, Martyn. Chaldercot, Leyburne-road, Dover.
1905. *Moysey, Miss E. L. Pitcroft, Guildford, Surrey.
1911. *Moysey, Lewis, B.A., M.B. St. Moritz, Ilkeston-road, Nottingham.
1912. ‡Mudie, Robert Francis. 6 Fintry-place, Broughty Ferry.
1902. ‡Muir, Arthur H. 7 Donegall-square West, Belfast.
1907. *Muir, Professor James. 31 Burnbank-gardens, Glasgow.
1874. ‡Muir, M. M. Pattison, M.A. Hillcrest, Farnham, Surrey.

Year of Election.

1915. §Muir, Ramsay. 140 Plymouth-grove, Manchester.
1909. ‡Muir, Robert R. Grain Exchange-building, Winnipeg, Canada.
1912. §Muir, Thomas Scott. 19 Seton-place, Edinburgh.
1904. ‡Muir, William, I.S.O. 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.
1913. §Muirhead, Professor J. H. The Rowans, Balsall Common, near Coventry.
1905. *Muirhead, James M. P., F.R.S.E. Dunlop Rubber Co., 3 Wallace-street, Bombay.
1876. *Muirhead, Robert Franklin, B.A., D.Sc. 64 Great George-street, Hillhead, Glasgow.
1902. ‡Mullan, James. Castlerock, Co. Derry.
1915. §Mullen, B. H. Salford Museum, Peel Park, Salford.
1904 ‡Mullinger, J. Bass, M.A. 1 Bene't-place, Cambridge.
1911. ‡Mumby, Dr. B. H. Borough Asylum, Milton, Portsmouth.
1898. ‡Mumford, C. E. Cross Roads House, Bouverie-road, Folkestone.
1901. *Munby, Alan E. 44 Downshire-hill, Hampstead, N.W.
1906. ‡Munby, Frederick J. Whixley, York.
1904. ‡Munro, A. Queens' College, Cambridge.
1909. ‡Munro, George. 188 Roslyn-road, Winnipeg, Canada.
1883. *MUNRO, ROBERT, M.A., M.D., LL.D. (Pres. H, 1893.) Elmbank, Largs, Ayrshire, N.B.
1909. ‡Munson, J. H., K.C. Wellington-crescent, Winnipeg, Canada.
1914. *Murchison, Roderick. Melbourne-mansions, Collins-street, Melbourne.
1911. ‡*Murdoch, W. H. F., B.Sc.* 14 *Howitt-road, Hampstead, N.W.*
1909. §Murphy, A. J. Vanguard Manufacturing Co., Dorrington-street, Leeds.
1908. ‡Murphy, Leonard. 156 Richmond-road, Dublin.
1908. ‡MURPHY, WILLIAM M., J.P. Dartry, Dublin.
1905 ‡Murray, Charles F. K., M.D. Kenilworth House, Kenilworth, Cape Colony.
1903. §Murray, Colonel J. D. Mytholmroyd, Wigan.
1914. ‡Murray, John Tullibardin New Farm Brisbane, Australia
1915. §Murray, Miss M. A. Edwards Library, University College, Gower-street, W.C.
1892. ‡Murray, T. S., D.Sc. 27 Shamrock-street, Dundee.
1909. ‡Murray, W. C. University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
1906. ‡Musgrove, Mrs. Edith M. S., D.Sc. The Woodlands, Silverdale, Lancashire.
1912. *Musgrove, James, M.D., Professor of Anatomy in the University of St. Andrews, N.B.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1906. ‡Myddelton-Gavey, E. H., J.P., F.R.G.S. Stanton Prior, Meads, Eastbourne.
1913. ‡Myddelton-Gavey, Miss Violet. Stanton Prior, Meads, Eastbourne.
1902. ‡*Myddleton, Alfred.* 62 *Duncairn-street, Belfast.*
1902. *Myers, Charles S., M.A., M.D. Great Shelford, Cambridge.
1909. *Myers, Henry. The Long House, Leatherhead.
1906. ‡Myers, Jesse A. Glengarth, Walker-road, Harrogate.
1915. §Myers, William. 7 Station-road, Cheadle Hulme.
1890. *MYRES, JOHN L., M.A., F.S.A. (Pres. H, 1909 ; Council, 1909–), Wykeham Professor of Ancient History in the University of Oxford. 101 Banbury-road, Oxford.
1914. *Myres, Miles Claude. 101 Banbury-road, Oxford.

Year of Election.

1886. ‡NAGEL, D. H., M.A. (Local Sec. 1894.) Trinity College, Oxford.
1890. ‡Nalder, Francis Henry. 34 Queen-street, E.C.
1908. ‡Nally, T. H. Temple Hill, Terenure, Co. Dublin.
1908. *Neal, Mrs. E. M. 10 Meadway, Hampstead Garden Suburb, N.W.
1909. ‡Neild, Frederic, M.D. Mount Pleasant House, Tunbridge Wells.
1883. *Neild, Theodore, M.A. Grange Court, Leominster.
1914. ‡Nelson, Miss Edith A., M.A., M.Sc. 131 Williams-road, East Prahran, Victoria.
1914. *Nettlefold, J. S. Winterbourne, Edgbaston Park-road, Birmingham.
1914. ‡Nettlefold, Miss. Winterbourne, Edgbaston Park-road, Birmingham.
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. *NEWALL, H. FRANK, M.A., F.R.S., F.R.A.S., Professor of Astrophysics in the University of Cambridge. Madingley Rise, Cambridge.
1912. ‡Newberry, Percy E., M.A., Professor of Egyptology in the University of Liverpool. Oldbury Place, Ightham, Kent.
1901. ‡Newbigin, Miss Marion, D.Sc. Royal Scottish Geographical Society, Edinburgh.
1901. ‡Newman, F. H. Tullie House, Carlisle.
1913. ‡Newman, L. F 2 Warkworth-street, Cambridge.
1889. ‡Newstead, A. H. L., B.A. 38 Green-street, Bethnal Green, N.E.
1912. *Newton, Arthur U. University College, W.C.
1892. ‡NEWTON, E. T., F.R.S., F.G.S. Florence House, Willow Bridge-road, Canonbury, N.
1914. §Newton, R. Bullen, F.G.S. British Museum (Natural History), South Kensington, S W.
1914. ‡Nicholls, Dr E. Brooke. 174 Victoria-street, North Melbourne.
1914. §Nicholls, Professor G. E. King's College, Strand, W.C.
1908. ‡Nicholls, W. A. 11 Vernham-road, Plumstead, Kent.
1908. ‡Nichols, Albert Russell. 30 Grosvenor-square, Rathmines, Co. Dublin.
1908. §Nicholson, J. W., M.A., D.Sc., Professor of Mathematics in King's College. Strand, W.C.
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.
1911. ‡Nicol, J. C., M.A. The Grammar School, Portsmouth.
1915. §Niven, James. Civic Buildings, 1 Mount-street, Manchester.
1908. ‡NIXON, The Right Hon. Sir CHRISTOPHER, Bart., M.D., LL.D., D.L. 2 Merrion-square, Dublin.
1916. §NOBLE, J. H. B. (LOCAL TREASURER, 1916) Sandhoe, Hexham, Northumberland.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., LL.D., F.R.S., F.L.S. The Red House, Berkhamsted.
1888. ‡Norman, George. 12 Brock-street, Bath.
1913. §Norman, Sir Henry, Bart., M.P. The Corner House, Cowley-street, S.W.
1912. ‡Norrie, Robert. University College, Dundee.
1913. ‡Norris, F. Edward. Seismograph Station, Hill View, Woodbridge Hill, Guildford.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. (Local Sec. 1895.) Constitution-hill, Ipswich.
1909. ‡Nugent, F. S. 81 Notre Dame-avenue, Winnipeg, Canada.

Year of Election.

1910. §Nunn, T. Percy, M.A., D.Sc., Professor of Education in the University of London. London Day Training College, Southampton-row, W.C.
1915. §Nuttall, Harry, M.P. Bank of England-chambers, Manchester.
1913. §Nuttall, T. E., M.D. Middleton, Huncoat, Accrington.
1912. ‡Nuttall, W. H. Cooper Laboratory for Economic Research, Rickmansworth-road, Watford.
1908. ‡Nutting, Sir John, Bart. St. Helen's, Co. Dublin.

1898. *O'Brien, Neville Forth. Greywell House, Woking.
1908. ‡O'Carroll, Joseph, M.D. 43 Merrion-square East, Dublin.
1913. §Ockenden, Maurice A., F.G.S. Oil Well Supply Company, Dashwood House, New Broad-street, E.C.
1883. ‡Odgers, William Blake, M.A., LL.D., K.C. 15 Old-square, Lincoln's Inn, W.C.
1910. *Odling, Marmaduke, M.A., F.G.S. Geological Department, The University, Leeds.
1858. *Odling, William, M.B., F.R.S., V.P.C.S. (Pres. B, 1864; Council, 1865–70.) 15 Norham-gardens, Oxford.
1911. *O'Donoghue, Charles H., D.Sc. University College, Gower-street, W.C.
1908. §O'Farrell, Thomas A., J.P. 30 Lansdowne-road, Dublin.
1915. §Ogden, C. K., M.A. Magdalene College, Cambridge.
1902. ‡Ogden, James Neal. Claremont, Heaton Chapel, Stockport.
1913. §Ogilvie, A. G. 15 Evelyn-gardens, S.W.
1876. ‡Ogilvie, Campbell P. Lawford-place, Manningtree.
1914. §Ogilvie, Mrs. Campbell P. Lawford-place, Manningtree.
1885. ‡Ogilvie, F. Grant, C.B., M.A., B.Sc., F.R.S.E. (Local Sec. 1892.) Board of Education, S.W
1912. §Ogilvy, J. W. 18 Bloomsbury-square, W.C.
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., Professor of Commerce in the National University of Ireland. 5 Victoria-terrace, Rathgar, 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.R.S., F.G.S. 8 North-street, Horsham, Sussex.
1912. §O'Leary, Rev. William, S.J. Rathfarnham Castle, Co. Dublin.
1914. ‡Oliver, Calder E. Manor-street, Brighton, Victoria.
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, W.C.
1914. §Oliver, H. G., C.E. Lara, Victoria, Australia.
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 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.

Year of Election.

1913. ‡Orange, J. A. General Electric Company, Schenectady, New York, U.S.A.
1905. ‡*O'Reilly, Patrick Joseph.* 7 *North Earl-street, Dublin.*
1884. *Orpen, Rev. T. H., M.A. Mark Ash, Abinger Common, Dorking.
1901. ‡Orr, Alexander Stewart. 10 Medows-street, Bombay, India.
1909. ‡Orr, John B. Crossacres, Woolton, Liverpool.
1908. *Orr, William. Dungarvan, Co. Waterford.
1904. *Orton, K. J. P., M.A., Ph.D., Professor of Chemistry in University College, Bangor.
1915. §Orwin, C. S. 7 Marston Ferry-road, Oxford.
1910. *Osborn, T. G. B., M.Sc., Professor of Botany in the University of Adelaide, South Australia.
1901. ‡Osborne, Professor W. A., D.Sc. The University, Melbourne
1908. ‡O'Shaughnessy, T. L. 64 Fitzwilliam-square, Dublin.
1887. ‡O'Shea, L. T., B.Sc. The University, Sheffield.
1884. ‡Osler, Sir William, Bart., M.D., LL.D., F.R.S., Regius Professor of Medicine in the University of Oxford. 13 Norham-gardens, Oxford.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1906. ‡Owen, Rev. E. C. St. Peter's School, York.
1903. *Owen, Edwin, M.A. Terra Nova School, Birkdale, Lancashire.
1911. §Owens, J. S., M.D., Assoc.M.Inst.C.E. 47 Victoria-street, S.W.
1910. *Oxley, A. E. Rose Hill View, Kimberworth-road, Rotherham.

1909. ‡Pace, F. W. 388 Wellington-crescent, Winnipeg, Canada.
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.
1883. ‡Page, G. W. Bank House, Fakenham.
1913. §Paget, Sir Richard, Bart. Old Fallings Hall, Wolverhampton.
1911. §Paget, Stephen, M.A., F.R.C.S. 21 Ladbroke-square, W.
1912. ‡Pahic, Paul. 52 Albert Court, Kensington Gore, S.W.
1911. ‡Paine, H. Howard. 50 Stow-hill, Newport, Monmouthshire.
1870. *Palgrave, Sir 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.
1915. *Parker, A. The University, Birmingham.
1904. ‡Parker, E. H., M.A. Thorneycreek, Hershel-road, Cambridge.
1909. §Parker, M. A., B.Sc., F.C.S. (Local Sec. 1909), Professor of Chemistry in the University of Manitoba, Winnipeg, Canada.
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.L.S., F.Z.S., F.R.G.S. Fairseat, High Wickham, Hastings.
1879. *Parkin, William. Broomhill House, Watson-road, Sheffield.
1911. ‡*Parks, Dr. G. J.* 18 *Cavendish-road, Southsea.*
1913. §Parry, Edward, M.Inst.C.E. Rossmore, Leamington.
1903. §Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo, near Liverpool.

Year of Election.

1908. ‡Parry, W. K., M.Inst.C.E. 6 Charlemont-terrace, Kingstown, Dublin.
1878. ‡Parsons, Hon. Sir C. A., K.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. Worting House, Basingstoke, Hants.
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.
1909. ‡Paterson, William. Ottawa, Canada.
1897. ‡Paton, D. Noel, M.D., F.R.S., Professor of Physiology in the University of Glasgow.
1883. *Paton, Rev. Henry, M.A. Airtnoch, 184 Mayfield-road, Edinburgh.
1884. *Paton, Hugh. Box 2646, Montreal, Canada.
1913. §Patrick, Joseph A., J.P. North Cliff, King's Heath, Birmingham.
1908. §Patten, C. J., M.A., M.D., Sc.D., Professor of Anatomy in the University of Sheffield.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1913. ‡Patterson, W. Hamilton, M.Sc. The Monksferry Laboratory, Birkenhead.
1913. *Pattin, Harry Cooper, M.A., M.D. King-street House, Norwich.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1883. ‡Paul, George. 32 Harlow Moor-drive, Harrogate.
1887. *Paxman, James. Standard Iron Works, Colchester.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1914. *Payne, Professor Henry, M.Inst.C.E. The University, Melbourne.
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., LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1912.) Geological Survey Office, George-square, Edinburgh.
1911. §Peake, Harold J. E. Westbrook House, Newbury.
1913. ‡Pear, T. H. Dunwood House, Withington, Manchester.
1886. *Pearce, Mrs. Horace. Collingwood, Manby-road, West Malvern.
1886. ‡Pearsall, H. D. Letchworth, Herts.
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. National Botanic Gardens, Kirstenbosch, Newlands, Cape Town.
1883. ‡Pearson, Miss Helen E. Oakhurst, Birkdale, Southport.
1906. ‡Pearson, Dr. Joseph. The Museum, Colombo, Ceylon.
1904. ‡Pearson, Karl, M.A., F.R.S., Professor of Eugenics in the University of London. 7 Well-road, Hampstead, N.W.
1909. ‡Pearson, William. Wellington-crescent, Winnipeg, Canada.
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.

Year of Election

1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1878. *Peek, William. Villa des Jonquilles, Rue des Roses, Monte Carlo.
1901. *Peel, Right Hon. Viscount. 52 Grosvenor-street, W.
1905. §Peirson, J. Waldie. P.O. Box 561, Johannesburg.
1915. §Pemberton, Granville. 49 Acresfield-road, Pendleton.
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. ‡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. 199 Piccadilly, W.
1884. ‡PERKIN, WILLIAM HENRY, LL.D., Ph.D., F.R.S., F.R.S.E. (Pres. B, 1900; Council, 1901–07), Waynflete Professor of Chemistry in the University of Oxford. 5 Charlbury-road, Oxford.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P., D.Sc. University College, Cardiff.
1909. ‡Perry, Rev. Professor E. Guthrie. 246 Kennedy-street, Winnipeg, Canada.
1874. *PERRY, Professor JOHN, M.E., D.Sc., LL.D., F.R.S. (GENERAL TREASURER, 1904- ; Pres. G, 1902; Pres. L, 1914; Council, 1901–04). British Association, Burlington House, London, W.
1913. ‡Perry, W. J. 7 York-view, Pocklington, Yorkshire.
1901. *Pertz, Miss D. F. M. 2 Cranmer-road, Cambridge.
1900. *PETAVEL, J. E., M.Sc., F.R.S., Professor of Engineering in the University of Manchester.
1914. *Peters, Thomas. Burrinjuck via Goondah, N.S.W.
1901. ‡Pethybridge, G. H., Ph.D. Royal College of Science, Dublin.
1910. *Petrescu, Captain Dimitrie, R.A., M.Eng. Scoala Superiora de Messern, Bucharest, Rumania.
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. Vale House, St. Helier, Jersey.
1886. ‡Phelps, Lieut.-General A. 23 Augustus-road, Edgbaston, Birmingham.
1911. ‡Philip, Alexander. Union Bank-buildings, Brechin.
1896. ‡Philip, G. Hornend, Eastcote, Middlesex.
1903. ‡*Philip, James C.* 20 *Westfield-terrace, Aberdeen.*
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1877. §Philips, T. Wishart. Elizabeth Lodge, Crescent-road, South Woodford, Essex.
1863. ‡Philipson, Sir G. H., D.C.L. 7 Eldon-square, Newcastle-on-Tyne.
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.
1910. *Phillips, P. P., Ph.D., Professor of Chemistry in the Thomason Engineering College, Rurki, United Provinces, India.
1890. ‡PHILLIPS, R. W., M.A., D.Sc., F.L.S., Professor of Botany in University College, Bangor. 2 Snowdon-villas, Bangor.
1909. *Phillips, Richard. 15 Dogpole, Shrewsbury.

Year of Election.

1915. §Phillips, Captain W. E. 7th Leinster Regiment. Kilworth Camp, Co. Cork.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1901. §Pickard, Robert H., D.Sc. Billinge View, Blackburn.
1885. *Pickering, Spencer P. U., M.A., F.R.S. Harpenden, Herts.
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.
1915. §Pilkington, Charles. The Headlands, Prestwich.
1905. ‡Pilling, Arnold. Royal Observatory, Cape Town.
1896. *Pilling, William. Rosario, Heene-road, West Worthing.
1905. ‡Pim, Miss Gertrude. Charleville, Blackrock, Co. Dublin.
1911. ‡Pink, H. R. The Mount, Fareham, Hants.
1911. ‡Pink, Mrs. H. R. The Mount, Fareham, Hants.
1911. ‡Pink, Mrs. J. E. The Homestead, Eastern-parade, Southsea.
1908. *Pio, Professor D. A. 14 Leverton-street, Kentish Town, N.W.
1908. ‡Pirrie, The Right Hon. Lord, LL.D., M.Inst.C.E. Downshire House, Belgrave-square, S.W.
1909. ‡Pitblado, Isaac, K.C. 91 Balmoral-place, Winnipeg, Canada.
1893. *Pitt, Walter, M.Inst.C.E. 3 Lansdown-grove, Bath.
1900. *Platts, Walter. Morningside, Scarborough.
1911. *Plimmer, R. H. A. Ranulf-road, Hampstead, N.W.
1915. §Plummer, Professor H. C., Royal Astronomer of Ireland. Dunsink Observatory, Co. Dublin.
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. 5 Wellclose-place, Leeds.
1913. ‡Pocock, R. J. St. Aidan's, 170 Eglinton-road, Woolwich, S.E.
1914. ‡Pollock, Professor J. A., D.Sc The University, Sydney, N.S.W.
1908. ‡Pollok, James H., D.Sc. 6 St. James's-terrace, Clonshea, Dublin.
1906. *Pontifex, Miss Catherine E. 7 Hurlingham-court, Fulham, S.W.
1891. ‡Pontypridd, Lord. Pen-y-lan, Cardiff.
1911. ‡Poore, Major-General F. H. 1 St. Helen's-parade, Southsea.
1907. §Pope, Alfred, F.S.A. South Court, Dorchester.
1900. *Pope, W. J., M.A., LL.D., F.R.S. (Pres. B, 1914), Professor of Chemistry in the University of Cambridge. Chemical Laboratory, The University, Cambridge.
1892. ‡Popplewell, W. C., M.Sc., Assoc.M.Inst.C.E. Bowden-lane, Marple, Cheshire.
1901. §Porter, Alfred W., B.Sc., F.R.S. 87 Parliament Hill-mansions, Lissenden-gardens, N.W.
1905. §Porter, J. B., D.Sc., M.Inst.C.E., Professor of Mining 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.

Year of Election.

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, 1905–12), Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Mrs. Wykeham House, Banbury-road, Oxford.
1913. ‡Poulton, Miss. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer, M.A. Wykeham Cottage, Woldingham, Surrey.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 11B Portland-place, W.
1887. §Pownall, George H. 20 Birchin-lane, E.C.
1913. ‡Poynting, Mrs. J. H. 10 Ampton-road, Edgbaston, Birmingham.
1908. ‡Praeger, R. Lloyd, B.A., M.R.I.A. Lisnamae, Rathgar, Dublin.
1907. *Prain, Lieut.-Col. Sir David, C.I.E., C.M.G., M.B., F.R.S. (Pres. K, 1909; Council, 1907–14.) Royal Gardens, Kew.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1913. *Prankerd, Miss Theodora Lisle. 25 Hornsey Lane-gardens, N.
1888. *Preece, W. Llewellyn, M Inst.C.E. 8 Queen Anne's-gate, S.W.
1904. §Prentice, Mrs. Manning. 27 Baldock-road, Letchworth.
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.
1914. ‡Preston, C. Payne. Australian Distillery Co., Byrne-street, South Melbourne.
1914. ‡Preston, Miss E. W. 153 Barry-street, Carlton, Victoria.
1903 §Price, Edward E. Oaklands, Oaklands-road, Bromley, Kent.
1888 ‡Price, L. L. F. R., M.A., F.S.S. (Pres. F, 1895; Council, 1898–1904.) Oriel College, Oxford.
1785. *Price, Rees. Walnuts, Broadway, Worcestershire.
1913. §Price, T. Slater. Municipal Technical School, Suffolk-street, Birmingham.
1897. *Price, W. A., M.A. 135 Sandyford-road, Newcastle-on-Tyne.
1914 ‡Priestley, Professor H. J. Edale, River-terrace, Kangaroo Point, Brisbane, Australia.
1908. §Priestley, J. H., B.Sc., Professor of Botany in the University of Leeds.
1909. *Prince, Professor E. E., LL.D., Dominion Commissioner of Fisheries. 206 O'Connor-street, Ottawa, Canada.
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. Care of E. C. S. Scholefield, Esq., Provincial Librarian, Victoria, B.C., Canada.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1903. ‡Pullen-Burry, Miss. Lyceum Club, 128 Piccadilly, W.
1904. ‡Punnett, R. C., M.A., F.R.S., Professor of Biology in the University of Cambridge. Caius College, Cambridge.
1885. ‡Purdie, Thomas, B.Sc., Ph.D., F.R.S., Emeritus Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.

Year of Election.

1913. ‡Purser, G. Leslie. Gwynfa, Selly Oak, Birmingham.
1913. ‡Purser, John, M.Sc. The University, Edgbaston, Birmingham.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1911. ‡Purvis, J. E. Corpus Christi College, Oxford.
1912. ‡Pycraft, Dr. W. P. British Museum (Natural History), Cromwell-road, S.W.
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.
1879. ‡Pye-Smith, R. J. 450 Glossop-road, Sheffield.
1911. ‡Pye-Smith, Mrs. R. J. 450 Glossop-road, Sheffield.

1893. ‡Quick, James. 22 Bouverie-road West, Folkestone.
1906. *Quiggin, Mrs. A. Hingston. 88 Hartington-grove, Cambridge.

1879. ‡Radford, R. Heber. 15 St. James's-row, Sheffield.
1912. ‡*Radok, F.* 12 *Central-hill, Upper Norwood, S.E.*
1911. §Rae, John T. National Temperance League, Paternoster House, Paternoster-row, E.C.
1887. *Ragdale, John Rowland. The Beeches, Stand, near Manchester.
1913. §Railing, Dr. A. H., B.Sc. The General Electric Co., Ltd., Witton, Birmingham.
1898. *Raisin, Miss Catherine A., D.Sc. Bedford College, York-place, Baker-street, W.
1896. *Ramage, Hugh, M.A. The Technical Institute, Norwich.
1894. *Rambaut, Arthur A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1908. ‡Rambaut, Mrs. Radcliffe Observatory, Oxford.
1912. ‡Ramsay, Colonel R. G. Wardlaw. Whitehill, Rosewell, Midlothian.
1876. *Ramsay, Sir William, K.C.B., Ph.D., D.Sc., F.R.S. (President, 1911 ; Pres. B, 1897 ; Council 1891–98). Beechcroft, Hazlemere, High Wycombe.
1883. ‡Ramsay, Lady. Beechcroft, Hazlemere, High Wycombe.
1915. §Ramsbottom, J., 61 Ennerdale-road, Richmond, Surrey.
1914. §Ramsbottom, J. W. 23 Rosebery-crescent, Newcastle-on-Tyne.
1913. ‡Ramsden, William. Blacker-road, Huddersfield.
1907. ‡Rankine, A. O., D.Sc. 68 Courtfield-gardens, 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, Dean Park, Bournemouth.
1903. ‡Rastall, R. H. Christ's College, Cambridge.
1914. ‡Rathbone, Herbert R. 15 Lord-street, Liverpool.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1913. ‡Raw, Frank, B.Sc., F.G.S. The University, Edmund-street, Birmingham.
1914. ‡*Rawes-Whittell, H. Manchester Hall,* 183 *Elizabeth-street, Sydney, N.S.W.*
1908. *Raworth, Alexander. St. John's Manor, Jersey.
1915. §Rawson, Christopher. 33 Manley-road, Manchester.
1905. ‡Rawson, Colonel Herbert E., C.B., R.E., F.R.G.S. Home Close, Heronsgate, Herts.
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.

Year of Election.

1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1912. §Rayner, Miss M. C., D.Sc. University College, Reading.
1897. *Rayner, Edwin Hartree, M.A. 40 Gloucester-road, Teddington, Middlesex.
1907. ‡Rea, Carleton, B.C.L. 34 Foregate-street, Worcester.
1913. §Read, Carveth, M.A. 73 Kensington Gardens-square, W.
1896. *Read, Sir Charles H., LL.D., F.S.A. (Pres. H, 1899.) British Museum, W.C.
1913. ‡Reade, Charles C. 3 Gray's Inn-place, Gray's Inn, W.C.
1914. ‡Reade, Mrs. C. C. 3 Gray's Inn-place, Gray's Inn, W.C.
1902. ‡Reade, R. H. Wilmount, Dunmurry.
1884. ‡Readman, J. B., D.Sc., F.R.S.E. Belmont, Hereford.
1890. *Redwood, Sir Boverton, Bart., D.Sc., F.R.S.E., F.C.S. The Cloisters, 18 Avenue-road, Regent's Park, N.W.
1908. ‡Reed, Sir Andrew, K.C.B., C.V.O., LL.D. 23 Fitzwilliam-square, Dublin.
1915. §Reed, H. A. The Red House, Bowdon.
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.
1903. ‡Reeves, E. A., F.R.G.S. Hillside, Reigate-road, Reigate.
1911. ‡Reeves, Hon. W. Pember. (Pres. F, 1911.) London School of Economics, Clare Market, W.C.
1906. *Reichel, Sir Harry R., M.A., LL.D., Principal of University College, Bangor. Penrallt, Bangor, North Wales.
1910. *Reid, Alfred, M.B., M.R.C.S. The Cranes, Tooting, S.W.
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. One Acre, Milford-on-Sea, Hants.
1903. *Reid, Mrs. E. M., B.Sc. One Acre, Milford-on-Sea, Hants.
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.
1901. *Reid, Hugh. Belmont, Springburn, Glasgow.
1901. ‡Reid, John. 7 Park-terrace, Glasgow.
1909. ‡Reid, John Young. 329 Wellington-crescent, Winnipeg, Canada.
1904. ‡Reid, P. J. Marton Moor End, Nunthorpe. R.S.O., Yorkshire.
1912. §Reid, Professor R. W., M.D. 37 Albyn-place, Aberdeen.
1897. ‡Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1892. ‡Reid, Thomas. Municipal Technical School, Birmingham.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1912. §Reinheimer, Hermann. 43 King Charles-road, Surbiton.
1875. ‡Reinold, A. W., C.B., M.A., F.R.S. (Council, 1890-95.) 3 Lennox-mansions, Southsea.
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.R.S., F.L.S. 28 Holmbush-road, Putney, S.W.
1914. ‡Rennie, Professor E. H., M.A., D.Sc. The University, Adelaide, Australia.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1906. ‡Rennie, John, D.Sc. Natural History Department, University of Aberdeen.

Year of Election.

1905. *Renton, James Hall. Rowfold Grange, Billingshurst, Sussex.
1912. ‡Rettie, Theodore. 10 Doune-terrace, Edinburgh.
1904. ‡Reunert, Theodore, M.Inst.C.E. P.O. Box 92, Johannesburg.
1912. ‡Rew, R. H., C.B. (Pres. M, 1915.) Board of Agriculture and Fisheries, 3 St. James's-square, S.W.
1905. §Reyersbach, Louis. Care of Messrs. Wernher, Beit, & Co., 1 London Wall-buildings, E.C.
1883. *Reynolds, A. H. 271 Lord-street, Southport.
1913. ‡Reynolds, J. H. Low Wood, Harborne, Birmingham.
1871. ‡Reynolds, James Emerson, M.D., D.Sc., F.R.S., F.C.S., M.R.I.A. (Pres. B, 1893; Council, 1893-99.) 3 Inverness-gardens, W.
1900 *Reynolds, Miss K. M. 8 Darnley-road, Notting Hill, W.
1906. ‡Reynolds, S. H., M.A., Sc.D., Professor of Geology in the University of Bristol.
1907. §Reynolds, W. G. Waterhouse Birstall Holt, near Leicester.
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.
1914. ‡Richardson, A. E V, M A., B Sc. Department of Agriculture, Melbourne.
1912. ‡Richardson, Harry, M.Inst.E.E. Electricity Supply Department, Dudhope Crescent-road, Dundee.
1889. ‡Richardson, Hugh, M.A. The Gables, Elswick-road, Newcastle-on-Tyne.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1901. *Richardson, Owen Willans, M.A., D.Sc., F.R.S., Wheatstone Professor of Physics in King's College, London, W.C.
1914 *Rideal, Eric K, B A., Ph.D. 28 Victoria-street, S W.
1883. *Rideal, Samuel, D Sc., F.C.S. 28 Victoria-street, S.W
1911. ‡Ridgeway, Miss A. R. 45 West Cliff, Preston.
1902. §Ridgeway, William, M.A., D.Litt., F.B.A. (Pres. H, 1908), Professor of Archæology in the University of Cambridge. Flendyshe, Fen Ditton, Cambridge.
1913. §Ridler, Miss C. C. Coniston, Hunsdon-road, Torquay.
1894. ‡Ridley, E. P., F.G.S. (Local Sec. 1895.) Burwood, Westerfield-road, Ipswich.
1881. *Rigg, Arthur. 150 Blomfield-terrace, W.
1883. *Rigg, Sir Edward, C B., I.S.O., M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1912. §Rintoul, Miss L. J. Lahill, Largo, Fife.
1910. ‡Ripper, William, Professor of Engineering in the University of Sheffield.
1903. *Rivers, W. H. R., M.D., F.R.S. (Pres. H, 1911.) St. John's College, Cambridge.
1913. ‡Rivett, A. C. D., B.A., Ph.D. (General Organising Secretary, 1914.) The University of Melbourne, Victoria.
1908. *Roaf, Herbert E., M.D., D.Sc. 44 Rotherwick-road, Hendon, N.W.
1898. *Robb, Alfred A., M.A., Ph.D. Lisnabreeny House, Belfast.
1914. ‡Robb, James Jenkins, M.D. Harlow, 19 Linden-road, Bournville, Birmingham.
1902. **Roberts, Bruno.* 30 *St. George's-square, Regent's Park, N.W.*
1887. *Roberts, Evan. 27 Crescent-grove, Clapham Common, S.W.

Year of Election.

1896. ‡Roberts, Thomas J. Ingleside, Park-road, Huyton, near Liverpool.
1913. §Robertson, Andrew. Engineering Laboratories, Victoria University, Manchester.
1897. ‡Robertson, Professor J. W., C.M.G., LL.D. The Macdonald College, St. Anne de Bellevue, Quebec, Canada.
1912. §Robertson, R. A., M.A., B.Sc., F.R.S.E., Lecturer on Botany in the University of St. Andrews.
1901. *Robertson, Robert, B.Sc., M.Inst.C.E. Carnbooth, Carmunnock, Lanarkshire.
1913. *Robins, Edward, M.Inst.C.E., F.R.G.S. Lobito, Angola, Portuguese South-West Africa.
1913. ‡Robinson, A. H., M.D. St. Mary's Infirmary, Highgate Hill, N.
1915. §Robinson, Arthur, Professor of Psychology in the University of Durham. Observatory House, Durham.
1886. *Robinson, Charles Reece. 176 Gerrard-street, Aston, Birmingham.
1909. ‡Robinson, E. M. 381 Main-street, Winnipeg, Canada.
1903. ‡Robinson, G. H. 1 Weld-road, Southport.
1902. ‡Robinson, Herbert C. Holmfield, Aigburth, Liverpool.
1911. ‡Robinson, J. J. 'West Sussex Gazette' Office, Arundel.
1902. ‡Robinson, James, M.A., F.R.G.S. Dulwich College, Dulwich, S.E
1912. §Robinson, James. Care of W. Buckley, Esq., Tynemouth-road, North Shields.
1888. ‡Robinson, John, M.Inst.C.E. 8 Vicarage-terrace, Kendal.
1908. *Robinson, John Gorges, B.A. Cragdale, Settle, Yorkshire.
1910. ‡Robinson, John Hargreaves. Cable Ship 'Norseman,' Western Telegraph Co., Caixa no Correu No. 117, Pernambuco, Brazil.
1899. *Robinson, Mark, M.Inst.C.E. Parliament-chambers, Westminster, S.W.
1914. ‡Robinson, Professor R. The University, Liverpool.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1908. ‡Robinson, Professor Robert, D.Sc. Lance House, Childwall-road, Wavertree, Liverpool.
1904. ‡Robinson, Theodore R. 25 Campden Hill-gardens, W.
1909. ‡Robinson, Captain W. 264 Roslyn-road, Winnipeg, Canada.
1909. ‡Robinson, Mrs. W. 264 Roslyn-road, Winnipeg, Canada.
1904. ‡Robinson, W. H. Kendrick House, Victoria-road, Penarth.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1912. ‡Robson, W. G. 50 Farrington-street, Dundee.
1915. §Roby, Frank Henry. New Croft, Alderley Edge.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1905. ‡Roebuck, William Denison, F.L.S. 259 Hyde Park-road, Leeds.
1908. ‡Rogers, A. G. L. Board of Agriculture and Fisheries, 8 Whitehall-place, S.W.
1898. ‡*Rogers, Bertram, M.D.* (*Local Sec.* 1898.) 11 *York-place, Clifton, Bristol.*
1913. ‡*Rogers, F., D.Eng., B.A. Rowardennan, Chelsea-road, Sheffield.*
1913. ‡Rogers, Sir Hallewell. Greville Lodge, Sir Harry's-road, Edgbaston, Birmingham.
1890. *Rogers, L. J., M.A., Professor of Mathematics in the University of Leeds. 6 Hollin-lane, Leeds.
1906. ‡Rogers, Reginald A. P. Trinity College, Dublin.
1909. ‡Rogers, Hon. Robert. Roslyn-road, Winnipeg, Canada.
1884. *Rogers, Walter. Care of Capital and Counties Bank, Falmouth.
1876. ‡Rollit, Sir A. K., LL.D., D.C.L., Litt.D. St. Anne's Hall, near Chertsey-on-Thames, Surrey.
1915. §Roper, R. E., M.A. Bedale School, Petersfield.
1905. ‡Rose, Miss G. Mabel. Ashley Lodge, Oxford.

Year of Election.

1883. *Rose, J. Holland, Litt.D. Walsingham, Millington-road, Cambridge.
1894. *Rose, Sir 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. 7 Gloucester-street, S.W.
1905. *Rosedale, Rev. W. E., D.D. St. Mary Bolton's Vicarage, South Kensington, S.W.
1900. ‡Rosenhain, Walter, B.A., F.R.S. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1914. §Rosenhain, Mrs. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1914. ‡Rosenhain, Miss. Warrawee, Coombe-lane, Kingston Hill, Surrey.
1914. ‡Ross, Alexander David, M.A., D.Sc., F.R.A.S., F.R.S.E., Professor of Mathematics and Physics in the University of Western Australia, Perth, Western Australia.
1909. ‡Ross, D. A. 116 Wellington-crescent, Winnipeg, Canada.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1912. ‡*Ross, Miss Joan M. Hazelwood, Warlingham, Surrey.*
1908. ‡Ross, Sir John, of Bladensburg, K.C.B. Rostrevor House, Rostrevor, Co. Down.
1902. ‡Ross, John Callender. 46 Holland-street, Campden-hill, W.
1915. §Ross, Roderick. Edinburgh.
1901. ‡Ross, Colonel Sir Ronald, K.C.B., F.R.S., Professor of Tropical Sanitation in the University of Liverpool. The University, Liverpool.
1891. *Roth, H. Ling. Briarfield, Shibden, Halifax, Yorkshire.
1911. *Rothschild, Right Hon. Lord, D.Sc., Ph.D., F.R.S. Tring Park, Tring.
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., B.A. 2 Exbury-road, Catford, S.E.
1905. §Rousselet, Charles F. Fir Island, Bittacy Hill, Mill Hill, N.W.
1901. ‡Rowallan, the Right Hon. Lord. Thornliebank House, Glasgow.
1903. *Rowe, Arthur W., M.B., F.G.S. Shottendane, Margate.
1890. ‡Rowley, Walter, M.Inst.C.E., F.S.A. Alderhill, Meanwood, Leeds.
1910. ‡Rowse, Arthur A., B.A., B.Sc. 190 Musters-road, West Bridgford, Nottinghamshire.
1901. *Rudorf, C. C. G., Ph.D., B.Sc. 52 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., F.R.S. The Elms, Adams-road, Cambridge.
1909. ‡Rumball, Rev. M. C., B.A. Morden, Manitoba, Canada.
1896. *Rundell, T. W., F.R.Met.Soc. Terras Hill, Lostwithiel.
1911. ‡Rundle, Henry, F.R.C.S. 13 Clarence-parade, Southsea.
1912. *Rusk, Robert R., M.A., Ph.D. 4 Barns-crescent, Ayr.
1904. ‡Russell, E. J., D.Sc. Rothamsted Experimental Station, Harpenden, Herts.
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.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1909. *Rutherford, Hon. Alexander Cameron. Strathcona, Alberta, Canada.
1907. §Rutherford, Sir Ernest, M.A., D.Sc., F.R.S. (Pres. A, 1909; Council, 1914–), Professor of Physics in the University of Manchester.

Year of Election.

1914. §Rutherford, Lady. 17 Wilmslow-road, Withington, Manchester.
1914. ‡Rutherford, Miss Eileen. 17 Wilmslow-road, Withington, Manchester.
1909. ‡Ruttan, Colonel H. N. Armstrong's Point, Winnipeg, Canada.
1908. ‡Ryan, Hugh, D.Sc. Omdurman, Orwell Park, Rathgar, Dublin.
1905. ‡Ryan, Pierce. Rosebank House, Rosebank, Cape Town
1909. ‡Ryan, Thomas. Assiniboine-avenue, Winnipeg, Canada.
1906. *Rymer, Sir Joseph Sykes. The Mount, York.

1903. ‡Sadler, M. E., C.B., LL.D. (Pres. L, 1906), Vice-Chancellor of the University of Leeds. 41 Headingley-lane, Leeds.
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.
1914. ‡St. John, J. R. Botanic Gardens, Melbourne.
1915. §Sainter, E. H. Care of Messrs. Steel, Peech & Tozer. Sheffield.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1904. ‡Salter, A. E., D.Sc., F.G.S. 5 Clifton-place, Brighton.
1911. §Sampson, Professor R. A., M.A., F.R.S., Astronomer Royal for Scotland. Royal Observatory, Edinburgh.
1901. ‡Samuel, John S., J.P., F.R.S.E. City Chambers, Glasgow.
1907. *Sand, Dr. Henry J. S. The Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1915. *Sandon, Harold. 51 Dartmouth Park-hill, Kentish Town, N.W.
1896. §Saner, John Arthur, M.Inst.C.E. Toolerstone, Sandiway, Cheshire.
1896. ‡Saner, Mrs. Toolerstone, Sandiway, Cheshire.
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, F.L.S. (Pres. K, 1913.) The Old Rectory, Girton, Cambridgeshire.
1907. ‡Sargent, H. C. Ambergate, near Derby.
1914. §Sargent, O. H. York, Western Australia.
1913. ‡Saundby, Robert, M.D. Great Charles-street, Birmingham.
1903. *Saunders, Miss E. R. (Council, 1914– .) Newnham College, Cambridge.
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.
1879. *Schäfer, Sir E. A., LL.D., D.Sc., M.D., F.R.S. (President, 1912; General Secretary, 1895–1900; Pres. I, 1894; Council, 1887–93), Professor of Physiology in the University of Edinburgh. Marly Knowe, North Berwick.
1914. ‡Schäfer, Lady. Marly Knowe, North Berwick.
1914. ‡Scharff, J. W. Knockranny, Bray, Co. Wicklow.
1914. ‡Scharff, Mrs. Knockranny, Bray, Co. Wicklow.
1888. *Scharff, Robert F., Ph.D., B.Sc., Keeper of the Natural History Department, National Museum, Dublin. Knockranny, Bray, Co. Wicklow.
1880. *Schemmann, Louis Carl. Neueberg 12, Hamburg.
1905. ‡Schönland, S., Ph.D. Albany Museum, Grahamstown, Cape Colony.

Year of Election.

1873. *Schuster, Arthur, Ph.D., Sec. R.S., F.R.A.S. (President; Pres. A, 1892; Council, 1887–93.) Yeldall, Twyford, Berks.
1883. *Sclater, W. Lutley, M A., F.Z.S. Odiham Priory, Winchfield.
1905. ‡Sclater, Mrs. W. L. Odiham Priory, Winchfield.
1913. §Scoble, Walter A., B.Sc., A.M.Inst.C.E. City and Guilds Technical College, Leonard-street, E.C.
1881. *Scott, Alexander, M.A., D.Sc., F.R.S., F.C.S. 34 Upper Hamilton-terrace, N.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; and Athenæum Club, Pall Mall, S.W.
1915. §Scott, Rev. Canon J. J. 65 Ardwick-green, Manchester.
1857. *Scott, Robert H., M.A., D.Sc., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.
1902. ‡Scott, William R., M.A., Litt.D. (Pres. F, 1915), Professor of Political Economy in the University of Glasgow.
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., Sc.D., F.R.S. Wyncote, Hills-road, Cambridge.
1906. *See, T. J. J., A.M., Ph.D., F.R.A.S., Professor of Mathematics, U.S. Navy. Naval Observatory, Mare Island, California.
1907. §Seligman, Dr. C. G. (Pres. H, 1915), Professor of Ethnology in the University of London. 36 Finchley-road, N.W.
1911. *Seligman, Mrs. C. G. 36 Finchley-road, N.W.
1913. §Seligmann, Miss Emma A. 61 Kirklee-road, Kelvinside, Glasgow.
1909. ‡Sellars, H. Lee. 225 Fifth-avenue, New York, U.S.A.
1888. *Senier, Alfred, M.D., Ph.D., D.Sc., F.C.S. (Pres. B, 1912), Professor of Chemistry in University College, Galway. 28 Herbert-park, Donnybrook, Co. Dublin.
1910. ‡Seton, R. S., B.Sc. The University, Leeds.
1895. *Seton-Karr, H. W. 8 St. Paul's-mansions, Hammersmith, W.
1892. *Seward, A. C., M.A., D.Sc., F.R.S., F.G.S. (Pres. K, 1903; Council, 1901–07; Local Sec. 1904), Professor of Botany in the University of Cambridge. The Master's Lodge, Downing College, Cambridge.
1913. ‡Seward, Mrs. The Master's Lodge, Downing College, Cambridge.
1914. ‡Seward, Miss Phyllis. The Master's Lodge, Downing College, Cambridge.
1899. ‡Seymour, Henry J., B.A., F.G.S., Professor of Geology in the National University of Ireland. Earlsfort-terrace, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1905. *Shackleford, W. C. Burnt Green, Worcestershire.
1904. ‡*Shackleton, Lieutenant Sir Ernest H., M.V.O., F.R.G.S.* 9 *Regent-street, S.W.*
1902. ‡Shaftesbury, The Right Hon. the Earl of, K.P., K.C.V.O. Belfast Castle, Belfast.
1913. ‡Shakespear, G. A., D.Sc., M.A. 21 Woodland-road, Northfield, Worcestershire.
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. Lawnside, Brockenhurst, Hants.

Year of Election.

1904. ‡Sharples, George. 181 Great Cheetham-street West, Higher Broughton, Manchester.
1914. ‡Shaw, A. G. Merton-crescent, Albert Park, Victoria.
1910. §Shaw, J. J. Sunnyside, Birmingham-road, West Bromwich.
1889. *Shaw, Mrs. M. S., B.Sc. Brookhayes, Exmouth.
1883. *Shaw, Sir Napier, M.A., Sc.D., F.R.S. (Pres. A, 1908; Council, 1895-1900, 1904-07.) Meteorological Office, Exhibition-road, South Kensington, S.W.
1883. ‡Shaw, Lady. 10 Moreton-gardens, South Kensington, S.W.
1915. §Shaw, Dr. P. E. University College, Nottingham.
1903. ‡Shaw-Phillips, T., J.P. The Times Library Club, 380 Oxford-street, W.
1912. ‡Shearer, C. Clare College, Cambridge.
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.
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, 1907-14), Professor of Physiology in the University of Oxford. 9 Chadlington-road, Oxford.
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.
1883. *Shillitoe, Buxton, F.R.C.S. Ardvernis, 3 Richmond-gardens, Bournemouth.
1887. *Shipley, Arthur E., M.A., D.Sc., F.R.S. (Pres. D, 1909; Council, 1904-11), Master of 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 Deronda-road, Herne Hill, S.E.
1908. ‡*Shorter, Lewis R., B.Sc.* 29 *Albion-street, W.*
1904. *Shrubsall, F. C., M.A., M.D. 4 Heathfield-road, Mill Hill Park, Acton, W.
1910. ‡Shuttleworth, T. E. 5 Park-avenue, Riverdale-road, Sheffield.
1889. ‡Sibley, Walter K., M.A., M.D. 6 Cavendish-place, W.
1902. ‡Siddons, A. W., M.A. Harrow-on-the-Hill, Middlesex.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
1914. *Sidgwick, Mrs. Henry (Pres. L, 1915). 27 Grange-road, Cambridge.
1913. *Sidgwick, N. V., M.A., D.Sc. Lincoln College, Oxford.
1873. *Siemens, Alexander, M.Inst.C.E. Caxton House, Westminster, S.W.
1905. ‡Siemens, Mrs. A. Caxton House, Westminster, S.W.
1914. ‡Silberberg, H. B. 8 O'Connell-street, Sydney, N.S.W.
1903. *Silberrad, Dr Oswald. Buckhurst Hill, Essex.
1915. *Simon, Councillor E. D. (Local Secretary, 1915.) 20 Mount-street, Manchester.
1871. *Simpson, Sir Alexander R., M.D., Emeritus Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1914. §Simpson, Dr. G. C. Meteorological Department, Simla, India.

Year of Election.

1913. *Simpson, J. A., M.A., D.Sc. 62 Academy-street, Elgin.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1909. ‡Simpson, Professor J. C. McGill University, Montreal, Canada.
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. 25 Chester-street, Edinburgh.
1907. ‡Simpson, Lieut.-Colonel R. J. S., C.M.G. 66 Shooter's Hill-road, Blackheath, S.E.
1909. *Simpson, Samuel. B.Sc, Director of Agriculture, Kampala, Uganda.
1909. ‡Simpson, Sutherland, M.D. Cornell University Medical College, Ithaca, New York, U.S.A.
1884. *Simpson, Professor W. J. R., C.M.G., M.D. 31 York-terrace, Regent's Park, N.W.
1909. ‡Sinclair, J. D. 77 Spence-street, Winnipeg.
1912. §Sinclair, Sir John R. G., Bart., D.S.O. Barrock House, Wick, N.B.
1907. *Sircar, Dr. Amrita Lal, L.M.S., F.C.S. 51 Sankaritola, Calcutta.
1905. *Sjögren, Professor H. Natural History Museum, Stockholm, Sweden.
1914. Skeats, E. W., D.Sc., F.G.S., Professor of Geology in the University, Melbourne.
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.
1910. ‡Skinner, J. C. 76 Ivy Park-road, Sheffield.
1898. ‡Skinner, Sidney, M.A. (Local Sec. 1904.) South-Western Polytechnic, Manresa-road, Chelsea, S.W.
1905. *Skyrme, C. G. Baltimore, 6 Grange-road, Upper Norwood, S.E.
1913. §Skyrme, Mrs. C. G. Baltimore, 6 Grange-road, Upper Norwood, S.E.
1913. *Slade, R. E., D.Sc. University College, Gower-street, W.C
1915. §Slater, Gilbert. Ruskin College, Oxford.
1887. ‡*Small, Evan W., M.A., B.Sc., F.G.S.* 48 *Kedleston-road, Derby.*
1915. *Smalley, J. Norton Grange, Castleton, Manchester.
1915. §Smalley, William. Springfield, Castleton, Manchester.
1903. *Smallman, Raleigh S. Eliot Lodge, Albemarle-road, Beckenham.
1902. ‡Smedley, Miss Ida. 36 Russell-square, W.C.
1911. ‡Smiles, Samuel. The Quarry, Sanderstead-road, Sanderstead, Surrey.
1911. §Smith, A. Malins, M.A. St. Audrey's Mill House, Thetford, Norfolk.
1914. ‡Smith, Professor A. Micah. School of Mines, Ballarat, Victoria.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Department of Chemistry, Columbia University, New York, U.S.A.
1908. ‡Smith, Alfred. 30 Merrion-square, Dublin.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1901. *Smith, Miss Annie Lorrain. 20 Talgarth-road, West Kensington, W.
1914. ‡Smith, Arthur Elliot. 4 Willow Bank, Fallowfield, Manchester.
1873. ‡Smith, C. Sidney-Sussex College, Cambridge.
1889. *Smith, Professor C. Michie, C.I.E., B.Sc., F.R.S.E., F.R.A.S. Winsford, Kodaikanal, South India.
1910. ‡Smith, Charles. 11 Winter-street, Sheffield.
1900. §Smith, E. J. Grange House, Westgate Hill, Bradford.
1913. *Smith, Miss E. M. 40 Owlstone-road, Newnham, Cambridge.
1908. ‡Smith, E. Shrapnell. 7 Rosebery-avenue, E.C.

Year of Election.

1915. §Smith, E. W. Fraser. (Local Secretary, 1916). 2 Jesmond-gardens, Newcastle-on-Tyne
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1901. §Smith, F. B. Care of A. Croxton Smith, Esq., Burlington House, Wandle-road, Upper Tooting, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1911. §Smith, F. E. National Physical Laboratory, Teddington, Middlesex.
1912. ‡Smith, Rev. Frederick. The Parsonage, South Queensferry.
1897. ‡Smith, G. Elliot, M.D., F.R.S. (Pres. H, 1912), Professor of Anatomy in the University of Manchester.
1914. §Smith, Mrs. G. Elliot. 4 Willow Bank, Fallowfield, Manchester.
1911. ‡Smith, Geoffrey W., M.A., F.L.S. New College, Oxford.
1903. *Smith, Professor H. B. Lees, M.A., M.P. The University, Bristol.
1910. §Smith, H. Bompas, M.A. Victoria University, Manchester.
1914. ‡Smith, H. G. Technological Museum, Sydney, N.S.W.
1889. *Smith, Sir H. Llewellyn, K.C.B., M.A., B.Sc., F.S.S. (Pres. F, 1910.) Board of Trade, S.W.
1860. *Smith, Heywood, M.A., M.D. 30 York-avenue, Hove.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
1902. ‡Smith, J. Lorrain, M.D., F.R.S., Professor of Pathology in the University of Edinburgh.
1903. *Smith, James. Pinewood, Crathes, Aberdeen.
1915. §Smith, Joseph. 28 Alton-street, Blackburn.
1914. ‡Smith, Miss L. Winsford, Kodaikanal, South India
1914. ‡Smith, Latimer Elliot. 4 Willow Bank, Fallowfield, Manchester.
1910. §Smith, Samuel. Central Library, Sheffield.
1894. §Smith, T. Walrond. Care of Frank Henderson, Esq., Thetford, Charles-street, Berkhamsted.
1910. ‡Smith, W. G., B.Sc., Ph.D. College of Agriculture, Edinburgh.
1896. *Smith, Rev. W. Hodson. 104–122 City-road, E.C.
1911. ‡Smith, W. Parnell. The Grammar School, Portsmouth.
1913. ‡Smith, Walter Campbell. British Museum (Natural History), Cromwell-road, S.W.
1885. *Smith, Watson. 34 Upper Park-road, Haverstock Hill, N.W.
1909. ‡Smith, William. 218 Sherbrooke-street, Winnipeg, Canada.
1883. ‡Smithells, Arthur, B.Sc., F.R.S. (Pres. B, 1907 ; Local Sec. 1890), Professor of Chemistry in the University of Leeds.
1909. ‡Smylie, Hugh. 13 Donegall-square North, Belfast.
1857. *Smyth, John, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1914. §Smyth, John, M.A., Ph.D. Teachers' College, Carlton, Victoria.
1908. §Smythe, J. A., Ph.D., D.Sc. 10 Queen's-gardens, Benton, Newcastle-on-Tyne.
1888. *Snape, H. Lloyd, D.Sc., Ph.D. Balholm, Lathom-road, Southport.
1913. *Snell, Sir John, M.Inst.C.E. 8 Queen Anne's-gate, S.W.
1905. ‡Soddy, F., M.A., F.R.S., Professor of Chemistry in the University of Aberdeen.
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. 48 Woodstock-road, Oxford.
1883. ‡Sollas, Mrs. 48 Woodstock-road, Oxford.
1915. §Somers, Edward. 4 Leaf-square, Pendleton.
1900. *Somerville, W., D.Sc., F.L.S., Sibthorpian Professor of Rural Economy in the University of Oxford. 121 Banbury-road, Oxford.

Year of Election.

1910. *Sommerville, Duncan M. Y. The University, St. Andrews, N.B.
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.
1915. §Sowerbutts, Harry. Manchester Geographical Society, 16 St. Mary's Parsonage, Manchester.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1913. §Sparke, Thomas Sparrow. 33 Birkby-crescent, Huddersfield.
1909. ‡Sparling, Rev. J. W., D.D. 159 Kennedy-street, Winnipeg, Canada.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1910. ‡Spearman, C. Birnam, Guernsey.
1912. ‡Speers, Adam, B.Sc., J.P. Holywood, Belfast.
1914 ‡Spencer, Professor W. Baldwin. C.M.G., M.A., D.Sc., F.R.S. The University, Melbourne.
1910. †*Spicer, Rev. E. C. The Rectory, Waterstock, Oxford.*
1894. ‡Spiers, A. H. Gresham's School, Holt, Norfolk.
1864. *Spiller, John, F.C.S. 2 St. Mary's-road, Canonbury, N.
1909. ‡Sprague, D. E. 76 Edmonton-street, Winnipeg, Canada.
1854. *Sprague, Thomas Bond, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1915. §Squier, George Owen. 43 Park-lane, W.
1888. *Stacy, J. Sargeant. 164 Shoreditch, E.
1903. ‡*Stallworthy, Rev. George B. The Manse, Hindhead, Haslemere, Surrey.*
1883. *Stanford, Edward, F.R.G.S. 12–14 Long-acre, W.C.
1914. *Stanley, Hon Sir Arthur, K.C.M.G. State Government House, Melbourne
1894. *Stansfield, Alfred, D.Sc. McGill University, Montreal, Canada.
1909. ‡Stansfield, Edgar. Mines Branch, Department of Mines, Ottawa, Canada.
1900. *Stansfield, Professor H., D.Sc. Hartley University College, Southampton.
1913. §Stanton, T. E., D.Sc., F.R.S. National Physical Laboratory, Teddington, Middlesex.
1911. §Stapf, Dr. Otto, F.R.S. Royal Gardens, Kew.
1915. §Stapledon, R. G. The Faugan, Llanbadarn, Aberystwyth.
1899. ‡Starling, E. H., M.D., F.R.S. (Pres. I, 1909; Council, 1914–), Professor of Physiology in University College London, W.C.
1898. ‡Stather, J. W., F.G.S. Brookside, Newland Park, Hull.
Staveley, T. K. Ripon, Yorkshire.
1907. §Staynes, Frank. 36–38 Silver-street, Leicester.
1910. ‡*Stead, F. B.* 80 *St. Mary's-mansions, Paddington, W.*
1900. *Stead, J. E., F.R.S. (Pres. B, 1910.) 11 Queen's-terrace, 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. 78A Lexham-gardens, W.
1914. ‡Steele, Professor B. D. The University, Brisbane, Australia.
1911. ‡Steele, L. J., M.I.E.E. H.M. Dockyard, Portsmouth.
1908. ‡Steele, Lawrence Edward, M.A., M.R.I.A. 18 Crosthwaite-park East, Kingstown, Co. Dublin.
1912. §Steggall, J. E. A., M.A., Professor of Mathematics in University College, Dundee. Woodend, Perth-road, Dundee.

Year of Election.

1911. ‡Stein, Sir Marc Aurel, K.C.I.E., D.Sc., D.Litt. Merton College, Oxford.
1909. ‡Steinkopj, Max. 667 Main-street, Winnipeg, Canada.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1915. §Stephens, Sir William. 2 Cathedral-street, Manchester.
1902. ‡Stephenson, G. Grianan, Glasnevin, Dublin.
1910. *Stephenson, H. K. Banner Cross Hall, Sheffield.
1911. ‡Stern, Moritz. 241 Bristol-road, Birmingham.
1909. ‡Stethern, G. A. Fort Frances, Ontario, Canada.
1908. *Steven, Alfred Ingram. M.A., B.Sc. 16 Great Clyde-street, Glasgow.
1906. ‡Stevens, Miss C. O. The Plain, Foxcombe Hill, Oxford.
1900. ‡Stevens, Frederick. (Local Sec. 1900.) Town Clerk's Office, Bradford.
1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpill, R.S.O.
1915. §Stevens, Marshall. Trafford Hall, Manchester.
1905. §Stewart, A. F. 343 Walmer-road, Toronto, Canada.
1916. §Stewart, A. W., D.Sc. 3 Annfield-road, Partick Hill, Glasgow.
1909. ‡Stewart, David A., M.D. 407 Pritchard-avenue, Winnipeg, Canada.
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, M.Inst C.E. St. George's-chambers, Cape Town.
1915. §Stewart, Walter. Ventnor Street Works, Bradford.
1911. ‡Stibbs, H. A. Portsea Island Gas Company, Commercial-road, Portsmouth.
1913. *Stiles, Walter. The University, Leeds.
1914. ‡Stillwell, J. L., M.Sc. University of Adelaide, South Australia
1914. ‡Stirling, Miss A. M. Care of Messrs. Elder & Co., 7 St. Helen's-place, Bishopsgate, E.C.
1914. ‡Stirling, E. C., C.M.G., M.A., M.D., Sc.D., F.R.S., Professor of Physiology in the University of Adelaide, South Australia.
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.
1883. *Stocker, W. N., M.A. Brasenose College, Oxford.
1898. *Stokes, Professor George J., M.A. 5 Fernhurst-villas, College-road, Cork.
1899. *Stone, Rev. F. J. Radley College, Abingdon.
1905. ‡Stoneman, Miss Bertha, D Sc. Huguenot College, Wellington, Cape Province.
1895. *Stoney, Miss Edith A. 20 Reynolds-close, Hampstead Way, N.W.
1908. *Stoney, Miss Florence A., M.D. 4 Nottingham-place, W.
1878. *Stoney, G. Gerald, F.R.S. Oakley, Heaton-road, Newcastle-upon-Tyne.
1883. ‡Stopes, Mrs. 4 Kemplay-road, Hampstead, N.W.
1903. *Stopes, Marie C., D.Sc., Ph.D., F.L.S. 14 Well-walk, Hampstead, N.W.
1915. §Stopford, John S. B. Woodbank, Higher Fence-road, Macclesfield.

Year of Election.

1910. §Storey, Gilbert. Department of Agriculture, Cairo.
1887. *Storey, H. L. Bailrigg, Lancaster.
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., Sc.D., F.R.S., F.G.S. (Pres. C, 1904), Director of the Geological Survey of Great Britain. Geological Museum, Jermyn-street, S.W.
1905. ‡Strange, Harold F. P.O. Box 2527, Johannesburg.
1908. *Stratton, F. J. M., M.A. Gonville and Caius College, Cambridge.
1914. ‡Street, Mr. Justice. Judges' Chambers, Supreme Court, Sydney, N.S.W.
1906. *Stromeyer, C. E. 9 Mount-street, Albert-square, Manchester.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M., 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. Care of Messrs. Barr & Stroud, Anniesland, Glasgow.
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.
1909. ‡Stupart, R. F. Meteorological Service, Toronto, Canada.
1879. *Styring, Robert. Brinkcliffe Tower, Sheffield.
1902. §Sully, H. T. Scottish Widows-buildings, Bristol.
1898. §Sully, T. N. Avalon House, Queen's-road, Weston-super-Mare.
1911. ‡Summers, A. H., M.A. 16 St. Andrew's-road, Southsea.
1887. *Sumpner, W. E., D.Sc. Technical School, Suffolk-street, Birmingham.
1908. ‡Sutherland, Alexander. School House, Gersa, Watten, Caithness.
1913. §Sutton, A. W. Bucklebury-place, Woolhampton, Berkshire.
1914. ‡Sutton, Harvey, M.D., B.Sc. Trinity College, Parkville, Victoria.
1911. ‡Sutton, Leonard, F.L.S. Hillside, Reading.
1911. ‡Sutton, W. L., F.I.C. Hillcroft, Eaton, Norwich.
1903. ‡*Swallow, Rev. R. D., M.A. Chigwell School, Essex.*
1905. ‡Swan, Miss Mary E. Overhill, Warlingham, Surrey.
1911. *Swann, Dr. W. F. G. Department of Terrestrial Magnetism Carnegie Institution of Washington, Washington, D.C. U.S.A.
1897. ‡Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1914. §Sweet, George, F.G.S. The Close, Brunswick, Victoria.
1914. ‡Sweet, Miss Georgina, D.Sc. The Close, Brunswick, Victoria.
1913. ‡Swift, Richard H. 4839 St. Lawrence-avenue, Chicago.
1914. ‡Swinburne, Hon. George. 139 Collins-street, Melbourne.
1887. §Swinburne, James, F.R.S., M.Inst.C.E. 82 Victoria-street, S.W.
1913. ‡Swinnerton, H. H. 441 Mansfield-road, Nottingham.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1913. §Sykes, Godfrey G. Desert Laboratory, Tucson, Arizona, U.S.A.
1896. *Sykes, Mark L., F.R.M.S. 10 Headingley-avenue, Leeds.
1902. *Sykes, Major P. Molesworth, C.M.G. Elcombs, Lyndhurst, Hampshire.
1902. *Sykes, Miss Ella C. Elcombs, Lyndhurst, Hampshire.
1906. ‡Sykes, T. P., M.A. 4 Gathorne-street, Great Horton, Bradford.
1914. ‡Syme, Mrs. D. York. Balwyn, Victoria.
1903. §Symington, Howard W. Brooklands, Market Harborough.

Year of Election.

1885. ‡SYMINGTON, JOHNSON, M.D., F.R.S., F.R.S.E. (Pres. H, 1903), Professor of Anatomy in Queen's University, Belfast.
1914. ‡Symington, Miss N. Queen's University, Belfast.
1908. ‡Synnott, Nicholas J. Furness, Naas, Co. Kildare

1910. *Tait, John, M.D., D.Sc. 44 Viewforth-terrace, Edinburgh.
1912. ‡Talbot, P. Amaury. Abbots Morton, Inkberrow, Worcestershire.
1904. §Tallack, H T. Clovelly, Birdhurst-road, South Croydon.
1913. §Tangye, William. Westmere, Edgbaston Park-road, Birmingham.
1903. *Tanner, Miss Ellen G. Parkside, Corsham, Wilts.
1892. *TANSLEY, ARTHUR G., M.A., F.L.S. Grantchester, near Cambridge.
1908. ‡TARLETON, FRANCIS A., LL.D. 24 Upper Leeson-street, Dublin.
1861. *Tarratt, Henry W. 25 Glyn-mansions, Addison Bridge, Kensington, W.
1902. ‡Tate, Miss. Rantalard, Whitehouse, Belfast.
1913. §Tattersall, W. M., D.Sc. The Museum, The University, Manchester.
1914. *Taylor, C. Z. 216 Smith-street, Collingwood, Victoria.
1908. ‡Taylor, Rev. Campbell, M.A. United Free Church Manse, Wigtown, Scotland.
1887. ‡Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
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.
1914. ‡Taylor, J. M, M.A Public Service Board, 4 O'Connell-street, Sydney, N.S.W.
1913. ‡Taylor, J. S. The Corinthians, Warwick-road, Acock's Green.
1915. §Taylor, J. W. Morecambe.
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.
1894. *Taylor, W. W., M.A. 66 St. John's-road, Oxford.
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., D.Sc., F.R.S., F.G.S. (Pres. C, 1893 : Council, 1894-1900, 1909-). Athenæum Club, S.W.
1906. *Teape, Rev. W. M., M.A. South Hylton Vicarage, Sunderland.
1910. ‡Tebb, W. Scott, M.A., M.D. 15 Finsbury-circus, E.C.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. Solheim, Cumberland Park, Acton, W.
1913. §TEMPLE, Sir R. C., Bart., C.I.E. (Pres. H, 1913.) The Nash, Worcester.
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.
1915. §Thowlis, J. Herbert. Daisy Mount, Victoria Park, Manchester.
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. The University, Manchester.
1906. *Thoday, Mrs. M. G. 6 Lyme-park, Chinley, Stockport.

Year of Election.

1870. ‡Thom, Colonel Robert Wilson, J.P. Brooklands, Lord-street West, Southport.
1891. *Thomas, Miss Clara. Pencerrig, Builth.
1903. *Thomas, Miss Ethel N., D.Sc. 3 Downe-mansions, Gondar-gardens, West Hampstead, N.W.
1913. ‡Thomas, H. H., M.A., B.Sc., F.G.S. 28 Jermyn-street, S.W.
1910. *Thomas, H. Hamshaw. Botany School, Cambridge.
1899. *Thomas, Mrs. J. W. Overdale, Shortlands, Kent.
1902 *Thomas, Miss M. Beatrice. Girton College, Cambridge.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1904 *Thomas, William, F.R.G.S. 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., C.B., B.A. (Pres. D, 1911; Local Sec. 1912), Professor of Zoology in University College, Dundee.
1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop
1907. *Thompson, Edwin. 25 Sefton-drive, Liverpool.
1883. *Thompson, Francis. Eversley, Haling Park-road, Croydon.
1904. *Thompson, G. R., B.Sc., Principal of and Professor of Mining in the South African School of Mines, Johannesburg.
1912. *Thompson, Rev. H. Percy. Kippington Vicarage, Sevenoaks.
1893. *Thompson, Harry J., M.Inst.C.E. Tregarthen, Garland's-road, Leatherhead.
1913. *Thompson, Mrs. Lilian Gilchrist. Kippington Vicarage. Sevenoaks.
1913. ‡Thompson, Peter. 14 Rotten Park-road, Edgbaston, Birmingham.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1913. *Thompson, Sidney Gilchrist. Kippington Vicarage, Sevenoaks.
1876. ‡Thompson, Silvanus Phillips, B.A., D.Sc, F.R.S., F.R.A.S. (Pres. G, 1907; Council, 1897-99, 1910-), Principal of 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.
1911. ‡Thompson, Mrs. W. H. 328 Assiniboine-avenue, Winnipeg.
1912. ‡Thompson, William Bruce. Thornbank, Dundee.
1912. §Thoms, Alexander. 7 Playfair-terrace, St. Andrews.
1894. ‡Thomson, Arthur, M.A., M.D, Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1913. ‡*Thomson, Arthur W., D.Sc.* 23 *Craven Hill-gardens, W.*
1912. §Thomson, D. C. 'Courier' Buildings, Dundee.
1909. *Thomson, E. 22 Monument-avenue, Swampscott, Mass., U.S.A.
1906. §Thomson, F. Ross, F.G.S. Hensill, Hawkhurst, Kent.
1914. §Thomson, Hedley J., Assoc.M.Inst.C.E. 14 Leonard-place, High-street, Kensington, W.
1890 *Thomson, Professor J. Arthur, M.A., F.R.S.E. Castleton House, Old Aberdeen.
1883. ‡Thomson, Sir J. J., O.M., M.A., Sc.D., D.Sc., Pres. R.S. (President, 1909; Pres. A, 1896; Council, 1893-95), Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1902. ‡Thomson, James Stuart. 4 Highfield, Chapel-en-le-Frith, Derbyshire.

Year of Election.

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. 18 Lansdowne-road, Holland Park, W.
1874. §Thomson, William, F.R.S.E., F.C.S. Royal Institution, Manchester.
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. 24 Manville-road, New Brighton, Cheshire.
1898. ‡Thorpe, Jocelyn Field, Ph.D., F.R.S., Professor of Organic Chemistry in the Imperial College of Science and Technology, S.W.
1871. ‡Thorpe, Sir T. E., C.B, Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. (Pres. B, 1890; Council, 1886-92.) Whinfield, Salcombe, Devon.
1899. §Threlfall, Richard, M.A., F.R.S. Oakhurst, Church-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.
1873. *Tiddeman, R. H., M.A., F.G.S. 298 Woodstock-road, Oxford.
1905. ‡Tietz, Heinrich, B.A., Ph D. South African College, Cape Town.
1874. ‡Tilden, Sir William A., D.Sc., F.R.S., F.C.S. (Pres. B, 1888; Council, 1898-1904.) The Oaks, Northwood, Middlesex.
1913. ‡Tilley, J. W. Field House, Harborne, Park-road, Birmingham.
1899. ‡Tims, H. W. Marett, M.A., M D., F.L S, Professor of Biology in the Royal Veterinary College. 11D Oxford and Cambridge-mansions, Marylebone-road, N.W.
1914. ‡Tims, Mrs. Marett. 11D Oxford and Cambridge-mansions, Marylebone-road, N.W.
1902. ‡Tipper, Charles J. R., B.Sc. 21 Greenside, Kendal.
1905. ‡Tippett, A. M., M.Inst.C.E. Cape Government Railways, Cape Town.
1911. ‡Tizard, Henry T. Oriel College, Oxford.
1900. *Tocher, J. F., D.Sc., F.I.C. Crown-mansions, 41½ Union-street, Aberdeen.
1912. §Todd, John A. The Nook, Alexandra Park, Nottingham.
1907. ‡Todd, Professor J. L. MacDonald College, Quebec, Canada.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1875. ‡Torr, Charles Hawley. 35 Burlington-road, Sherwood, Nottingham.
1909. ‡Tory, H. M. Edmonton, Alberta, Canada.
1912. ‡Tosh, Elmslie. 11 Reform-street, Dundee.
1901. ‡Townsend, J. S., 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. (Pres. K, 1910), Regius Professor of Botany in the University of Aberdeen.
1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1902. ‡*Travers, Ernest J. Dunmurry, Co. Antrim.*

Year of Election.

1914. *Trechmann, C. T. Hudworth Tower, Castle Eden, Durham.
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1908. §Treen, Rev. Henry M., B.Sc. 3 Stafford-road, Weston-super-Mare.
1908. ‡Tremain, Miss Caroline P., B.A. Alexandra College, Dublin.
1911. §Tremearne, Mrs., LL.A., F.L.S. 105 Blackheath-park, S.E.
1914. ‡Tremearne, Mrs. Ada J. Mandeville Hall, Clendon-road, Toorak, Victoria.
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. Stoner Hill, Petersfield, Hants.
1871. ‡Trimen, Roland, M.A., F.R.S., F.L.S., F.Z.S. Glaslyn, Waterden-road, Guildford.
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.
1914. ‡Trouton, Eric The Rydings, Redington-road, Hampstead, N.W.
1887. *Trouton, Frederick T., M.A., Sc.D, F.R.S (Pres. A, 1914; Council, 1911-14.) The Rydings, Redington-road, Hampstead, N.W.
1914. ‡Trouton, Mrs The Rydings, Redington-road, Hampstead, N.W.
1898. *Trow, Albert Howard, D.Sc., F.L.S., Professor of Botany in University College, Cardiff.
1913. ‡Tschugaeff, Professor L. The University, Petrograd.
1885. *Tubby, A. H., M.S., F.R.C.S. 68 Harley-street, W.
1905. §Turmeau, Charles. Claremont, Victoria Park, Wavertree, Liverpool.
1912. ‡Turnbull, John. City Chambers, Dundee.
1901. §Turnbull, Robert, B.Sc. Department of Agriculture and Technical Instruction, Dublin.
1914. ‡Turner, Dr. A. J. Wickham-terrace, Brisbane, Australia.
1893. ‡Turner, Dawson, M.D., F.R.S.E. 37 George-square, Edinburgh.
1913. §Turner, G. M. Kenilworth.
1894. *Turner, H. H., M.A., D.Sc., F.R.S., F.R.A.S. (General Secretary, 1913- ; Pres. A, 1911), Professor of Astronomy in the University of Oxford. University 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. 75 Middleton Hall-road, King's Norton.
1910. *Turner, W. E. S. The University, Sheffield.
1890. *Turpin, G. S., M.A., D.Sc. High School, Nottingham.
1907. §Tutton, A. E. H., M.A., D.Sc., F.R.S. (Council, 1908-12.) Duart, Yelverton, South Devon.
1915. *Tweedale, Samuel. Sanbridge House, Castleton, Manchester.
1886. *Twigg, G. H. Rednall, near Birmingham.
1899. ‡Twisden, John R., M.A. 14 Gray's Inn-square, W.C.
1907. §Twyman, F. 75A Camden-road, N.W.
1865. ‡Tylor, Sir Edward Burnett, D.C.L., LL.D., F.R.S. (Pres. H, 1884; Council, 1896-1902.) Linden, Wellington, Somerset.
1911. *Tyndall, A. M., M.Sc. The University, Bristol.

Year of Election.

1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.
1912. ‡Tyrrell, G. W. Geological Department, The University, Glasgow.

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. Grove House, Leighton Park School, Reading.
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.
1909. ‡Urquhart, C. 239 Smith-street, Winnipeg, Canada.
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.
1912. ‡Valentine, C. W. Queen's University, Belfast
1908. ‡Valera, Edward de. University College, Blackrock, Dublin.
1865. *Varley, S. Alfred. Arrow Works, Jackson-road, Holloway, N.
1907. §Varley, W. Mansergh, M.A., D.Sc., Ph.D. Morningside, Eaton-crescent, Swansea.
1903. ‡Varwell, H. B. Sittaford, West-avenue, Exeter.
1909. *Vassall, H., M.A. The Priory, Repton, Burton-on-Trent.
1888. *Vaughan, Mrs. 750 Pacific-building, San Francisco.
1905. ‡Vaughan, E. L. Eton College, Windsor.
1913. ‡Vaughton, T. A. Livery-street, Birmingham.
1881. ‡Veley, V. H., M.A., D.Sc., F.R.S. 8 Marlborough-place, St. John's Wood, N.W.
1883. *Verney, Lady. Plâs Rhoscolyn, Holyhead.
1904. *Vernon, H. M., M.A., M.D. 5 Park Town, Oxford.
1896. *Vernon, Thomas T. Shotwick Park, Chester.
1896. *Vernon, Sir William, Bart. 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, Grey Abbey, Co. Down.
1909. ‡Wadge, Herbert W., M.D. 754 Logan-avenue, Winnipeg, Canada.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1914. ‡Wadsworth, Arthur. Commonwealth Parliament, Melbourne.
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. Haberdashers' School, Cricklewood, N.W.
1902. ‡Wainwright, Joel. Finchwood, Marple Bridge, Stockport.

Year of Election.

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. Care of George Lloyd, Esq., 7 Coper's Cope-road, Beckenham, Kent.
1893 ‡Walker, Alfred O., F.L.S. Ulcombe-place, Maidstone, Kent
1890. ‡Walker, A Tannett. The Elms, Weetwood, Leeds.
1901 *Walker, Archibald, M.A., F.I.C. Newark Castle, Ayr, N.B.
1904. §Walker, E. R. Nightingales, Adlington, Lancashire.
1911. *Walker, E. W. Ainley, M.A. University College, Oxford.
1905. ‡Walker, Mrs. Ainley. 31 Holywell, Oxford.
1897. *Walker, Sir Edmund, C.V.O., D.C.L., F.G.S. (Local Sec. 1897) Canadian Bank of Commerce, Toronto, Canada.
1915. §Walker, Edward J., M.D. Hey Lee Combs, Chapel-en-le-Frith.
1891. ‡Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
1894. *Walker, G. T., M.A., D.Sc., F.R.S., F.R.A.S. Red Roof, Simla, India.
1897. ‡Walker, George Blake, M.Inst.C.E. Tankersley Grange, near Barnsley.
1913. §Walker, George W., M.A., F.R.S. 63 Lensfield-road, Cambridge.
1906. ‡Walker, J. F. E. Gelson, B.A. 45 Bootham, York.
1894. *Walker, James, M.A. 30 Norham-gardens, Oxford.
1910. *Walker, James, D.Sc., F.R.S. (Pres. B, 1911), Professor of Chemistry in the University of Edinburgh. 5 Wester Coates-road, Edinburgh.
1906. ‡Walker, Dr. Jamieson. 37 Charnwood-street, Derby.
1909. ‡Walker, Lewie D. Lieberose, Monteith-road, Cathcart, Glasgow.
1915. §Walker, Professor Miles. School of Technology, Manchester.
1907. ‡Walker, Philip F., F.R.G.S. 36 Prince's-gardens, S.W.
1909. §Walker, Mrs. R. 3 Riviera-terrace, Rushbrooke, Queenstown, Co. Cork.
1908. *Walker, Robert. Ormidale, Combe Down, Bath.
1888. ‡Walker, Sydney F. 1 Bloomfield-crescent, Bath.
1896. §Walker, Colonel William Hall, M.P. Gateacre, Liverpool.
1914. ‡Walkom, A. B. The University, Brisbane, Australia.
1910. ‡Wall, G. P., F.G.S. 32 Collegiate-crescent, Sheffield.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1911. ‡Wall, Thomas F., D.Sc., Assoc.M.Inst.C.E. The University, Birmingham.
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.
1913. *Waller, J. C., B.A. 32 Grove End-road, N.W.
1913. *Waller, Miss M. D., B.Sc., 32 Grove End-road, N.W.
1913. *Waller, W. W., B.A., 32 Grove End-road, N.W.
1915. §Wallis, B. C. Bandora, Granville-road, North Finchley, N.
1895. ‡Wallis, E. White, F.S.S. Royal Sanitary Institute and Parkes Museum, 90 Buckingham Palace-road, S.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.
1903. ‡Walsh, W. T. H. Kent Education Committee, Caxton House, Westminster, S.W.
1895. ‡Walsingham, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.

Year of Election.

1902. *Walter, Miss L. Edna. 18 Norman-road, Heaton Moor, Stockport.
1904. *Walters, William, jun. Albert House, Newmarket.
1887. ‡WARD, Sir A. W., M.A., Litt.D., Master of Peterhouse, Cambridge.
1911. ‡Ward, A. W. Town Hall, Portsmouth.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1914. ‡Ward, L. Keith, B.E. Burnside-road, Kensington Park, South Australia.
1914. ‡Ward, Thomas W. Endcliffe Vale House, Sheffield.
1905. ‡Warlow, Dr. G. P. 15 Hamilton-square, Birkenhead.
1887. ‡WARREN, 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.
1913. §Warren, William Henry, LL.D., M.Sc., M.Inst.C.E., Challis Professor of Engineering in the University of Sydney, N.S.W.
1913. ‡Warton, Lieut.-Colonel R. G. St. Helier, Jersey.
1914. ‡Waterhouse, G. A., B.Sc. Royal Mint, Sydney, N.S.W.
1875. *WATERHOUSE, Major-General J. Hurstmead, Eltham, Kent.
1905. ‡Watermeyer, F. S., Government Land Surveyor. P.O. Box 973, Pretoria, South Africa.
1916. §Waters, Miss Charlotte M. Cotswold, Hurst Green, Oxted, Surrey.
1900. ‡Waterston, David, M.D., F.R.S.E. King's College, Strand, W.C.
1909. §Watkinson, Professor W. H. The University, Liverpool.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1901. *WATSON, ARNOLD THOMAS, F.L.S. Southwold, Tapton Crescent-road, Sheffield.
1886. *Watson, C. J. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1909. ‡WATSON, Colonel Sir C. M., K.C.M.G., C.B., R.E., M.A. (Pres. E, 1912.) 16 Wilton-crescent, S.W.
1906. ‡Watson, D. M. S. University College, London, W.C.
1909. ‡Watson, Ernest Ansley, B.Sc. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1892. ‡Watson, G., M.Inst.C.E. 5 Ruskin-close, Hampstead Way, N.W.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1915. *Watson, G. N. Trinity College, Cambridge.
1906. *Watson, Henry Angus. 3 Museum-street, York.
1913. ‡Watson, John D., M.Inst.C.E. Tyburn, Birmingham.
1894. *WATSON, Professor W., D.Sc., F.R.S. 7 Upper Cheyne-row, S.W.
1915. *Watson, Walter, B.Sc. Taunton School, Somerset.
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.
1913. *Watt, James. 28 Charlotte-square, Edinburgh.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1873. *WATTS, W. MARSHALL, D.Sc. Shirley, Venner-road, Sydenham, S.E.
1883. *WATTS, W. W., M.A., M.Sc., F.R.S., F.G.S. (Pres. C, 1903; Council, 1902-09), Professor of Geology in the Imperial College of Science and Technology, London, S.W.
1870. §Watts, William, M.Inst.C.E., F.G.S. Kenmore, Wilmslow, Cheshire.
1911. ‡Waxweiler, Professor E. Solvay Institute, Brussels.
1905. ‡Way, W. A., M.A. The College, Graaf Reinet, South Africa.
1907. ‡Webb, Wilfred Mark, F.L.S. The Hermitage, Hanwell, W.
1910. ‡Webster, Professor Arthur G. Worcester, Massachusetts, U.S.A.
1910. ‡Webster, William, M.D. 1252 Portage-avenue, Winnipeg, Canada.

Year of Election.

1904. §Wedderburn, Ernest Maclagan, D.Sc., F.R.S.E. 7 Dean Park-crescent, Edinburgh.
1903. ‡Weekes, R. W., A.M.Inst.C.E. 65 Hayes-road, Bromley, Kent.
1914. §Weir, G. North Mine, Broken Hill, New South Wales.
1890 *Weiss, Frederick Ernest, D.Sc., F.L.S. (Pres. K, 1911; Council, 1914–), 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.
1911. ‡Welldon, Right Rev. J. E. C., D.D. (Pres. L, 1911.) The Deanery, Manchester.
1908. ‡*Wellisch, E. M.* 17 *Park-street, Cambridge.*
1881. ‡Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1911. *Welsford, Miss E. J. Imperial College of Science and Technology, S.W.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. The Limes, Walland's Park, Lewes.
1886. *Wertheimer, Julius, D.Sc., B.A., F.I.C., Dean of the Faculty of Engineering in the University of Bristol.
1910. §West, G. S., M.A., D.Sc., Professor of Botany in the University of Birmingham.
1903 ‡Westaway, F. W. 1 Pemberley crescent, Bedford.
1882. *Westlake, Ernest, F.G.S. Fordingbridge, Salisbury.
1900. ‡Wethey, E. R., M.A., F.R.G.S. 4 Cunliffe-villas, Manningham, Bradford.
1909. ‡Wheeler, A. O., F.R.G.S. The Alpine Club of Canada, Sidney, B.C., Canada.
1893. *Whetham, W. C. D., M.A., F.R.S. Upwater Lodge, Cambridge.
1888. ‡Whidborne, Miss Alice Maria. Charanté, Torquay.
1912. ‡Whiddington, R., M.A., D.Sc. St. John's College, Cambridge.
1913. ‡Whipp, E. M. 14 St. George's-road, St. Anne's-on-Sea.
1912. *Whipple, F. J. W., M.A. Meteorological Office, South Kensington, S.W.
1898. *Whipple, Robert S. Scientific Instrument Company, Cambridge.
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.
1897. ‡Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡White, A. Silva. 42 Stevenage-road, S.W.
1908. ‡White, Mrs. A. Silva. 42 Stevenage-road, S.W.
1911. ‡White, Miss E. L., M.A. Day Training College, Portsmouth.
1913. §White, Mrs. E. W. Anelgate, Harborne-road, Edgbaston, Birmingham.
1904. ‡White, H. Lawrence, B.A. 33 Rossington-road, Sheffield.
1885. *White, J. Martin. Balruddery, Dundee.
1914. ‡White, Dr. Jean. Prickly Pear Experimental Station, Dulacca, Queensland, Australia.
1910. *White, Mrs. Jessie, D.Sc., B.A. 49 Gordon-mansions, W.C.
1912. §White, R. G., M.Sc. University College, Bangor, North Wales.
1877. *White, William. 20 Hillersdon-avenue, Church-road, Barnes, S.W.
1904. ‡Whitehead, J. E. L., M.A. (Local Sec. 1904.) Guildhall, Cambridge.

Year of Election.

1913. ‡Whitehouse, Richard H., M.Sc. Queen's University, Belfast.
1905. ‡Whiteley, Miss M. A., D.Sc. Imperial College of Science and Technology, S.W.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. Municipal Science and Technical School, West Bromwich.
1907. *Whitley, E. 13 Linton-road, Oxford.
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., Professor of Mathematics in the University of Edinburgh.
1901. ‡Whitton, James. City Chambers, Glasgow.
1905. §Wibberley, C., M.V.O. Care of Parr's Bank, Ltd., Cornmarket, Derby.
1913. §Wicksteed, Rev. Philip H., M.A. (Pres. F, 1913.) Childrey, Wantage, Berkshire.
1912. §Wight, Dr. J. Sherman. 30 Schermerhorn-street, Brooklyn, U.S.A.
1889. *Wilberforce, L. R., M.A., Professor of Physics in the University of Liverpool.
1914. †Wilcock, J L 9 East-road, Lancaster.
1887. *Wilde, Henry, D.Sc., D.C.L., F.R.S. The Hurst, Alderley Edge, Cheshire.
1910. §Wilkins, C. F. Lower Division, Eastern Jumna Canal, Delhi.
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.
1915. *Willans, J. B. Dolfargan, Kerry, Montgomeryshire.
1913. ‡Willcox, J. Edward, M.Inst.C.E. 27 Calthorpe-road, Edgbaston, Birmingham.
1903. ‡Willett, John E. 3 Park-road, Southport.
1904. *Williams, Miss Antonia. 6 Sloane-gardens, S.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. 22 Lansdown-place, Cheltenham.
1883. *Williams, Mrs. J. Davies. 5 Chepstow-mansions, Bayswater, W.
1888. *Williams, Miss Katharine I. 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.
1894. *Williamson, Mrs. Janora. 18 Rosebery-gardens, Crouch End, N.
1910. ‡Williamson, K. B., Central Provinces, India. Care of Messrs. Grindlay & Co., 54 Parliament-street, S.W.
1913. ‡Willink, H. G. Hillfields, Burghfield, Mortimer, Berkshire.
1895. ‡Willink, W. (Local Sec. 1896.) 14 Castle-street, Liverpool.
1895. ‡Willis, John C., M.A., D.Sc., F.L.S. 48 Jesus-lane, Cambridge.
1896. ‡Willison, J. S. (Local Sec. 1897.) Toronto, Canada.
1913. *Wills, L. J., M.A., F.G.S. The University, Birmingham.
1899. §Willson, George. Lendarac, Sedlescombe-road, St. Leonards-on-Sea.
1899. §Willson, Mrs. George. Lendarac, Sedlescombe-road, St. Leonards-on-Sea.
1913. ‡Wilmore, Albert, D.Sc., F.G.S. Fernbank, Colne.
1911. *Wilmott, A. J., B.A. Natural History Museum, S.W.

Year of Election.

1911. §Wilsmore, Professor N. T. M., D.Sc. The University, Perth, Western Australia.
1911. ‡Wilsmore, Mrs. The University, Perth, Western Australia.
1908. §Wilson, Miss. Glenfield, Deighton, Huddersfield.
1901. ‡Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
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. Low Slack, Queen's-road, Kendal.
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 Suffolk-street, Pall Mall, S.W.
1901. §Wilson, Charles John, F.R.G.S. Deanfield, Hawick, Scotland.
1912. ‡Wilson, David, M.A., D.Sc. Carbeth, Killearn, N.B.
1904. ‡Wilson, David, M.D. Glenfield, Deighton, Huddersfield.
1912. *Wilson, David Alec. 1 Broomfield-road, Ayr.
1900. *Wilson, Duncan R. 44 Whitehall-court, S.W.
1895. ‡Wilson, Dr. Gregg. Queen's University, Belfast,
1914. ‡Wilson, H. C. Department of Agriculture, Research Station, Werribee, Victoria.
1901. ‡Wilson, Harold A., M.A., D.Sc., F.R.S., Professor of Physics in the Rice Institute, Houston, Texas.
1902. *Wilson, Harry, F.I.C. 32 Westwood-road, Southampton.
1879. ‡Wilson, Henry J., M.P. Osgathorpe Hills, Sheffield.
1910. *Wilson, J. S. 29 Denbigh-street, S.W.
1913. §Wilson, Professor J. T., M.B., F.R.S. University of Sydney, Sydney, N.S.W.
1908. §Wilson, Professor James, M.A., B.Sc. 40 St. Kevin's-park, Dartry-road, Dublin.
1879. ‡Wilson, John Wycliffe. Easthill, East Bank-road, Sheffield.
1901. *Wilson, Joseph, F.R.M.S. The Hawthorns, 3 West Park-road, Kew Gardens, Surrey.
1908. *Wilson, Malcolm, D.Sc., F.L.S., Lecturer in Mycology and Bacteriology in the University of Edinburgh. Royal Botanic Gardens, Edinburgh.
1909. §Wilson, R. A. Hinton House, Londonderry.
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.
1861. ‡Wilson, Thomas Bright. Ghyllside, Wells-road, Ilkley, Yorkshire.
1887. §Wilson, W. Battlehillock, Kildrummy, Mossat, Aberdeenshire.
1909. ‡Wilson, W. Murray. 29 South-drive, Harrogate.
1910. ‡Wilton, T. R., M.A., Assoc.M.Inst.C.E. 18 Westminster-chambers, Crosshall-street, Liverpool.
1907. §Wimperis, H. E., M.A. 16 Reynolds-close, Hampstead Way, N.W.
1910. ‡Winder, B. W. Ceylon House, Sheffield.
1886. ‡Windle, Sir Bertram C. A., M.A., M.D., D.Sc., F.R.S., President of University 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.
1914. ‡Witkiewicz, S. Care of Dr. Malinowski, London School of Economics, Clare Market, W.C.
1913. ‡Wohlgemuth, Dr. A. 44 Church-crescent, Muswell Hill, N.
1875. ‡Wolfe-Barry, Sir John, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1898; Council, 1899–1903, 1909–10.) Delahay House, 15 Chelsea Embankment, S.W.

Year of Election.

1915. §Wolff, C. E. The Clough, Hale, Cheshire.
1905. ‡Wood, A., jun. Emmanuel College, Cambridge.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1875. *Wood, George William Rayner. Singleton Lodge, Manchester.
1878. ‡Wood, Sir H. Trueman, M.A. Royal Society of Arts, John-street, Adelphi, W.C.; and Prince Edward's-mansions, Bayswater, W.
1908. ‡Wood, Sir Henry J. 4 Elsworthy-road, N.W.
1883. *Wood, J. H. 21 Westbourne-road, Birkdale, Lancashire.
1912. §Wood, John K. 304 Blackness-road, Dundee.
1904. *Wood, T. B., M.A. (Pres. M, 1913), 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. A. Care of Messrs. Stilwell & Harley, 4 St. James'-street, Dover.
1896. *Woodhead, Professor G. Sims, M.D. Pathological Laboratory, Cambridge.
1911. §Woodhead, T. W., Ph.D., F.L.S. Technical College, Huddersfield.
1912. *Wood-Jones, F., D.Sc., Professor of Anatomy in the University of London. New Selma, Epsom, Surrey.
1906. *Woodland, Dr. W. N. F. Zoological Department, The Muir Central College, Allahabad, United Provinces, India.
1904. ‡Woods, Henry, M.A. Sedgwick Museum, 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. (Pres. C, 1909; Council, 1903-10, 1915-), 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.
1912. †Woodward, Mrs. C. J. 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.
1894. *Woodward, John Harold. 8 Queen Anne's-gate, Westminster, S.W.
1909. *Woodward, Robert S. Carnegie Institution, Washington, U.S.A.
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.R.C.Inst., F.R.G.S., F.R.E.S., F.S.S., M.R.I.A. 14 Waterloo-road, Dublin.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1915. *Woolley, Hermann. Fairhill, Kersal, Manchester.
1914. ‡Woolnough, Professor W. S., D.Sc. University of Western Australia, Perth, Western Australia.
1912. *Wordie, James M., B.A. St. John's College, Cambridge.
1908. ‡*Worsdell, W. C.* 2 *Woodside, Bathford, Bath.*
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1901. ‡*Worth, J. T. Oakenrod Mount, Rochdale.*
1904. ‡Worthington, A. M., C.B., F.R.S. 5 Louisa-terrace, Exmouth.
1908. *Worthington, James H., M.A., F.R.A.S., F.R.G.S. The Observatory, Four-Marks, Alton.
1906. ‡Wragge, R. H. Vernon. York.
1910. ‡Wrench, E. G. Park Lodge, Baslow, Derbyshire.

Year of Election.

1906. ‡Wright, Sir Almroth E., M.D., D.Sc., F.R.S., Professor of Experimental Pathology in the University of London. 6 Park-crescent, W.
1914. ‡Wright, A. M. Islington, Christchurch, New Zealand.
1883. *Wright, Rev. Arthur, D.D. Queens' College, Cambridge.
1909. ‡Wright, C. S., B.A. Caius College, Cambridge.
1914. ‡Wright, Gilbert. Agricultural Department, The University, Sydney, N.S.W.
1874. ‡Wright, Joseph, F.G.S. 4 Alfred-street, Belfast.
1884. ‡Wright, Professor R. Ramsay, M.A., B.Sc. Red Gables, Headington Hill, Oxford.
1904. ‡*Wright, R. T. Goldieslie, Trumpington, Cambridge.*
1911. ‡Wright, W. B., B.A., F.G.S. 14 Hume-street, Dublin.
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.
1911. ‡Wyllie, W. L., R.A. Tower House, Tower-street, Portsmouth.
1899. ‡Wynne, W. P., D.Sc., F.R.S. (Pres. B, 1913), Professor of Chemistry in the University of Sheffield. 17 Taptonville-road, Sheffield.

1901. *Yapp, R. H., M.A., Professor of Botany in the Queen's University, Belfast
*Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Campsie Dene, Blanefield, Stirlingshire.
1913. *Yates, H. James, F.C.S., M.I.Mech.E. Redcroft, Four Oaks, Warwickshire.
1905. ‡Yerbury, Colonel. Army and Navy Club, Pall Mall, S.W.
1909. §Young, Professor A. H. Trinity College, Toronto, Canada.
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.
1909. ‡Young, F. A. 615 Notre Dame-avenue, Winnipeg, Canada.
1913. *Young, Francis Chisholm. La Nonette de la Forêt, Geneva.
1894. *Young, George, Ph.D. 46 Church-crescent, Church End, Finchley, N.
1909. §Young, Herbert, M.A., B.C.L., F.R.G.S. Arnprior, Ealing, W.
1901. *Young, John. 2 Montague-terrace, Kelvinside, Glasgow.
1885. ‡Young, R. Bruce, M.A., M.B. 8 Crown-gardens, Dowanhill, Glasgow.
1909. ‡Young, R. G. University of North Dakota, North Chautauqua, North Dakota, U.S.A.
1901. ‡Young, Robert M., B.A. Rathvarna, Belfast.
1883. *Young, Sydney, D.Sc., F.R.S. (Pres. B, 1904), Professor of Chemistry in the University of Dublin. 12 Raglan-road, Dublin.
1887. ‡Young, Sydney. 29 Mark-lane, E.C
1911. ‡Young, T. J. College of Agriculture, Holmes Chapel, Cheshire.
1907. *Young, William Henry, M.A., Sc.D., Hon. Dr. ès Sc. Math., F.R.S., Professor of the Philosophy and History of Mathematics in the University of Liverpool. La Nonette de la Forêt, Geneva, Switzerland.
1903. ‡Yoxall, Sir J. H., M.P. 67 Russell-square, W.C.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Local Office, U.S.A. Weather Bureau, Washington, U.S.A.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18.)
1913. Dr. O. Backlund. Pulkowa, Russia.
1913. Professor C. Barrois. Université, Lille, France.
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
1887. Hofrath Professor A. Bernthsen, Ph.D. Anilenfabrik, Ludwigshafen, Germany.
1913. Professor K. Birkeland. Universitet, Christiania.
1890. Professor Dr. L. Brentano. Friedrichstrasse 11, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Christiania, Norway.
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.
1913. Professor H. S. Carhart. University of Michigan, Ann Arbor, Michigan, U.S.A.
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.
1913. Professor R. Chodat. Université, Geneva.
1887. F. W. Clarke. Care of the Smithsonian Institution, Washington, D.C., U.S.A.
1913. Professor H. Conwentz. Elssholzstrasse 13, Berlin W. 57.
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, Liége, Belgium.
1913. Professor Carl Diener. Universität, Vienna.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
1901. Professor J. Elster. Wolfenbuttel, Germany.
1913. Professor A. Engler. Universität, Berlin.
1913. Professor Giulio Fano. Istituto di Fisiologia, Florence.
1901. Professor W. G. Farlow. Harvard, U.S.A.
1874. Dr. W. Feddersen. Carolinenstrasse 9, Leipzig.
1913. Professor Chas. Féry. École Municipale de Physique et de Chimie Industrielles, 42 rue Lhomond, Paris.
1886. Dr. Otto Finsch. Altewiekring, No.19b, Braunschweig, Germany.
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, Liége, Belgium.

Year of Election.

1913. Professor M. von Frey. Universität, Würzburg.
1892. Professor Dr. Gustav Fritsch. Berlinerstrasse 30, Berlin.
1881. Professor C. M. Gariel. 6 rue Edouard Détaille, Paris.
1901. Professor Dr. H. Geitel. Wolfenbüttel, Germany.
1889. Professor Gustave Gilson. l'Université, Louvain, Belgium.
1913. Professor E. Gley. 14 rue Monsieur le Prince, Paris.
1889. A Gobert. 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, U.S.A.
1913. Professor P. H. von Groth. Universität, Munich.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1913. Yves Guyot. 95 rue de Seine, Paris.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 30 Langdon-street, Cambridge, Mass., U.S.A.
1913. Professor A. Haller. 10 rue Vauquelin, Paris.
1913. Professor H. J. Hamburger. Physiological Institute, Gröningen.
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.
1913. Professor A. F. Holleman. Universiteit, Amsterdam.
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. Soldino, Lugano, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy, Annapolis, Maryland, U.S.A.
1887. Professor C. Julin. 159 rue de Fragnée, Liége.
1876. Dr. Giuseppe Jung. Bastioni Vittoria 21, Milan.
1913. Professor Hector Jungersen. Universitet, Copenhagen.
1913. Professor J. C. Kapteyn. Universiteit, Groningen.
1913. Professor A. E. Kennelly. Harvard University, Cambridge, Massachusetts, U.S.A.
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.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1913. Professor D. J. Korteweg. Universiteit, Amsterdam.
1913. Professor A. Kossel. Physiologisches Institut, Heidelberg.
1894. Maxime Kovalevsky. 13 Avenue de l'Observatoire, Paris, France.
1913. Ch. Lallemand, Directeur-Général des Mines. 58 Boulevard Emile-Augier, Paris.
1872. M. Georges Lemoine. 76 rue Notre Dame des Champs, Paris.
1901. Professor Philipp Lenard. Schlossstrasse 7, Heidelberg.
1883. Dr. F. Lindemann. Franz-Josefstrasse 12/I, Munich.
1887. Professor Dr. Georg Lunge. Rämistrasse 56, Zurich, V.
1913. Professor F. von Luschan. Universität, Berlin.
1894. Professor Dr. Otto Maas. Universität, Munich
1913. Professor E. Mahaim. Université de Liége, Belgium.
1887. Dr. C. A. von Martius. Voss-strasse 8, Berlin, W.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1894. Professor G. Mittag-Leffler. Djursholm, Stockholm.
1897. Professor Oskar Montelius. St. Paulsgatan 11, Stockholm, Sweden.
1913. Professor E. H. Moore. University of Chicago, U.S.A.
1897. Professor E. W. Morley, LL.D. West Hartford, Connecticut, U.S.A.

Year of Election.

1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.
1913. Professor F. R. Moulton. University of Chicago, U.S.A.
1889. Dr. F. Nansen. Lysaker, Norway.
1894. Professor R. Nasini. Istituto Chimico, Via S. Maria, Pisa, Italy.
1913. Professor E. Naville. Université, Geneva.
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.
1887. Professor Georg Quincke. Bergstrasse 41, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich. Sonnenstrasse 7.
1913. Professor Reinke. Universität, Kiel.
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1913. Dr. Hans Reusch. Universitet, Christiania.
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.
1913. Professor A. Rothpletz. Universitat, Munich.
1913. Professor H. Rubens. Universitat, Berlin.
1895. Professor Carl Runge. Wilhelm Weberstrasse 21, Göttingen, Germany.
1901. General Rykatchew. Universitetskaia-linia, 1, Petrograd.
1913. Dr. C. Schoute. De Biet, Holland.
1874. Dr. G. Schweinfurth. Kaiser Friedrichstrasse 8, Berlin.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1887. Ernest Solvay. 25 rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. 312 East 2nd-street, Cincinnati, Ohio, U.S.A.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, U.S.A.
1889. Wladimir Vernadsky. Imperial Academy of Sciences, Petrograd.
1913. Professor M. Verworn. Universität, Bonn.
1886. Professor Jules Vuylsteke. 21 rue Belliard, Brussels, Belgium.
1887. Professor Dr. Leonhard Weber. Moltkestrasse 60, Kiel.
1913. Professor Max Weber. Universiteit, Amsterdam.
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.
1913. Professor R. W. Wood. Johns Hopkins University, Baltimore, U.S.A.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND.

Aberystwyth, National Library of Wales.
Belfast, Queen's University.
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.
——, National Library of Ireland.
Dundee, University College.
——, Albert Institute.
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.
——, Board of Agriculture and Fisheries.
——, Chemical Society.
——, City and Guilds (Engineering) College.
——, Civil Engineers, Institution of.
——, Geological Society.
——, Geology, Museum of Practical.
——, Greenwich Royal Observatory.
——, Guildhall Library.
——, Institution of Electrical Engineers.
——, Institution of Mechanical Engineers.
London, Intelligence Office, Central Department of Political Information.
——, King's College.
——, Linnean Society.
——, 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 Sanitary Institute.
——, Royal Society.
——, Royal Society of Arts.
——, Royal Statistical Society.
——, United Service Institution.
——, University College.
——, War Office, Library.
——, Workers' Educational Association. 14 Red Lion Square, W.C.
——, 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.
——, Kew Observatory, Richmond.
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.
Liége .....University Library.
Lisbon .....Academia Real des Sciences.
Milan .....The Institute.
Modena .....Royal Academy.
Moscow .....Society of Naturalists
—— .....University Library.
Munich.....University Library.
Naples .....Royal Academy of Sciences.
—— .....Zoological Station.
Paris.....Association Française pour l'Avancement des Sciences.
—— .....Geographical Society.
—— .....Geological Society.
—— .....Royal Academy of Sciences.
—— .....School of Mines.
Petrograd ....University Library.
—— .....Imperial Observatory.
Pultova .....Imperial Observatory.
Rome .....Accademia dei Lincei.
—— .....Collegio Romano.
—— .....Italian Geographical Society.
—— .....Italian Society of Sciences.
Rumania ....Rumanian Association for the Advancement of Science.
Spain .....Asociacion para el Progreso de las Ciencias.
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.
—— .....Royal Asiatic Society.
Calcutta .....Royal Asiatic Society.
—— .....Hooghly College.
Calcutta.....Medical College.
—— .....Presidency College.
Ceylon .....The Museum, Colombo.
Madras .....The Observatory.
—— .....University Library.
Tokyo .....Imperial University.

AFRICA.

Cape Town ....National Botanic Gardens, Newlands.
—— .....The Royal Observatory.
—— .....South African Association for the Advancement of Science.
—— .....South African Public Library.
Grahamstown ..Rhodes University College.
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.
Edmonton....University of Alberta.
Guelph .....Ontario Agricultural College.
Kingston .....Queen's University.
Manitoba ....Historical and Scientific Society.
—— .....The University.
Massachusetts .Marine Biological Laboratory, Woods Hole.
Mexico .....Sociedad Científica 'Antonio Alzate.'
Missouri .....Botanical Garden.
Montreal .....Council of Arts and Manufactures.
Montreal .....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.
Uruguay.....General Statistical Bureau and Library, Montevideo.
Washington...Board of Agriculture.
—— .....Bureau of Ethnology.
—— .....Bureau of Standards, Department of Commerce and Labour.
—— .....Coast and Geodetic Survey.
—— .....Library of Congress.
—— .....Naval Observatory.
—— .....Smithsonian Institution.
—— .....United States Geological Survey of the Territories.

AUSTRALIA.

Adelaide .....Public Library of South Australia.
—— .....Royal Geographical Society.
—— .....The University.
Brisbane .....Queensland Museum.
—— .....Queensland Public Library.
Melbourne .....Public Library.
Sydney .....Public Works Department.
—— .....Australian Museum.
—— .....Library, Department of Mines.
Tasmania .....Royal Society.
Victoria.....The Colonial Government.

NEW ZEALAND.

Canterbury .....The Museum.
Wellington .....New Zealand Institute (Dominion Museum).

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