REPORT
OF THE
ANNUAL MEETING, 1937
(107TH YEAR)

NOTTINGHAM
SEPTEMBER 1-8

LONDON
OFFICE OF THE BRITISH ASSOCIATION
BURLINGTON HOUSE, LONDON, W. 1

1937
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Section G. President’s Address.

Page 153, lines 17, 18. Read [The National Physical Laboratory] had already a total staff of approximately 548. It has now 724.

Section I. President’s Address.

Further work since Nottingham has shown a discrepancy between Benedict’s and DuBois’s results. Benedict’s results (Fig. 1, 2) are incompatible with the variable combustion ratio, but are difficult to accept, because on the alternative theory of the constant combustion ratio an evolution of oxygen would be associated with an evolution of heat. DuBois’s results are compatible with both theories.

Calculations on pp. 196, 197 of Cal. per litre of oxygen resulting from conversion, at rest, after food and in muscular work also conform to both theories so far as they relate to R.Qs. from about 0.72 to 1.

Those results of DuBois, where there is a large change of rectal temperature during the experiment, with a resulting large difference between ‘direct calorimetric’ and ‘eliminated’ heat are uncertain and these form a large proportion of the results outside the theoretical limits for \( O_2 \) and Cal. in Fig. 3, and also account for the apparent similarity of the results of DuBois and Benedict mentioned on p. 191. Consequently there is no absolute disproof of the variable combustion ratio; but the constancy of the \( CO_2 \) over the range of quotients among other things makes the constant combustion ratio more probable and basal metabolism is still best defined and measured by the \( CO_2 \) alone as indicated on p. 200 and the other deductions from p. 200 onwards stand. It is hoped that a final discussion of this subject will appear in the Guy’s Hospital Reports.

Section L. President’s Address.

Page 242, line 30. For ‘terrestrial’ read ‘territorial.’
BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

OFFICERS & COUNCIL, 1937-38.

PATRON.
HIS MAJESTY THE KING.

PRESIDENT, 1937.
Prof. Sir Edward Poulton, D.Sc., I.L.D., F.R.S.

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The Rt. Hon. Lord Rayleigh, F.R.S.

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Secretary.—G. V. Jacks.
Local Secretary.—R. N. Dowling.

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President.—Prof. J. Ritchie.
Secretary.—Dr. C. Tierney.
<table>
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<tr>
<th>Date of Meeting</th>
<th>Where held</th>
<th>Presidents</th>
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<tr>
<td>1834, Sept. 27</td>
<td>York</td>
<td>Viscount Milton, D.C.L., F.R.S.</td>
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<td>1834, July</td>
<td>Oxford</td>
<td>The Rev. W., Buckland, F.R.S.</td>
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<td>1834, Aug. 15</td>
<td>Cambridge</td>
<td>The Rev. A. Sedgwick, F.R.S.</td>
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<td>1834, Sept. 8</td>
<td>Edinburgh</td>
<td>Sir T. M. Brisbane, D.C.L., F.R.S.</td>
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<td>1835, July 2</td>
<td>Dublin</td>
<td>The Rev. Provost Lloyd, L.L.D., F.R.S.</td>
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<td>1835, Aug. 22</td>
<td>Liverpool</td>
<td>Sir John Lubbock, F.R.S.</td>
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<td>1835, Sept. 16</td>
<td>Newcastle-on-Tyne</td>
<td>The Earl of Burlington, F.R.S.</td>
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<td>1835, Aug. 10</td>
<td>Birmingham</td>
<td>The Duke of Northumberland, F.R.S.</td>
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<td>1835, Aug. 17</td>
<td>Glasgow</td>
<td>The Rev. W. Vernon Harcourt, F.R.S.</td>
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<td>1836, July 20</td>
<td>Plymouth</td>
<td>The Marquis of Breadalbane, F.R.S.</td>
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<td>1836, Aug. 23</td>
<td>Manchester</td>
<td>The Rev. W. Whewell, F.R.S.</td>
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<td>1837, Aug. 17</td>
<td>Cork</td>
<td>The Lord Francis Egerton, F.G.S.</td>
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<td>1837, Sept. 26</td>
<td>York</td>
<td>The Earl of Rosse, F.R.S.</td>
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<td>1837, Aug. 8</td>
<td>Swansea</td>
<td>Sir John F. W. Herschel, Bart., F.R.S.</td>
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<td>1838, Aug. 9</td>
<td>Cambridge</td>
<td>Sir Roderick I. Marchion, Bart., F.R.S.</td>
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<td>1838, Sept. 23</td>
<td>Oxford</td>
<td>Sir Robert H. Inglis, Bart., F.R.S.</td>
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<td>1838, Aug. 5</td>
<td>Swansea</td>
<td>The Marquis of Northampton, Pres.R.S.</td>
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<td>1839, July 21</td>
<td>Edinburgh</td>
<td>Sir David Brewster, K.H., F.R.S.</td>
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<td>1839, July 6</td>
<td>Ipswich</td>
<td>Lieut.-General Sabine, F.R.S.</td>
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<td>1839, Sept. 1</td>
<td>Belfast</td>
<td>William Hopkins, F.R.S.</td>
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<td>1839, Sept. 3</td>
<td>Hull</td>
<td>The Earl of Harrowby, F.R.S.</td>
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<td>1839, Sept. 14</td>
<td>Liverpool</td>
<td>The Duke of Argyll, F.R.S.</td>
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<td>1839, Sept. 12</td>
<td>Glasgow</td>
<td>Prof. C. G. B. Daubeney, M.D., F.R.S.</td>
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<td>1839, Sept. 22</td>
<td>Leeds</td>
<td>Richard Owen, M.D., D.C.L., F.R.S.</td>
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<td>1839, Sept. 14</td>
<td>Aberdeen</td>
<td>H.R.H. The Prince Consort</td>
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<td>1839, Sept. 26</td>
<td>Oxford</td>
<td>The Lord Wrottesley, M.A., F.R.S.</td>
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<td>1839, Sept. 23</td>
<td>Manchester</td>
<td>Sir William Fairbairn, F.R.S.</td>
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<td>1839, Oct. 1</td>
<td>Cambridge</td>
<td>The Rev. Professor Willis, M.A., F.R.S.</td>
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<td>1839, Sept. 13</td>
<td>Bath</td>
<td>Sir Charles Lyell, Bart., M.A., F.R.S.</td>
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<td>1839, Sept. 6</td>
<td>Birmingham</td>
<td>Prof. J. Phillips, M.A., L.L.D., F.R.S.</td>
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<td>1839, Aug. 22</td>
<td>Durham</td>
<td>William R. Grove, Q.C., F.R.S.</td>
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<td>1839, Aug. 4</td>
<td>Duddes</td>
<td>The Duke of Buccleuch, K.C.B., F.R.S.</td>
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<td>1839, Aug. 19</td>
<td>Norwich</td>
<td>Dr. Joseph D. Hooker, F.R.S.</td>
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<td>1839, Aug. 18</td>
<td>Exeter</td>
<td>Prof. G. G. Stokes, D.C.L., F.R.S.</td>
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<td>1839, Sept. 14</td>
<td>Liverpool</td>
<td>Prof. T. H. Huxley, L.L.D., F.R.S.</td>
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<td>1839, Aug. 16</td>
<td>Edinburgh</td>
<td>Sir John Thomson, M.A., F.R.S.</td>
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<td>1839, Aug. 14</td>
<td>Brighton</td>
<td>Dr. W. B. Carpenter, F.R.S.</td>
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<td>1839, Sept. 17</td>
<td>Bradford</td>
<td>Prof. A. W. Williamson, F.R.S.</td>
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<td>1839, Aug. 19</td>
<td>Belfast</td>
<td>Prof. J. Tyndall, L.L.D., F.R.S.</td>
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<td>1839, Sept. 25</td>
<td>Bristol</td>
<td>Sir John Hawkshaw, F.R.S.</td>
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<td>1839, Sept. 3</td>
<td>Birmingham</td>
<td>Prof. T. Andrews, M.D., F.R.S.</td>
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<td>1839, Aug. 7</td>
<td>Plymouth</td>
<td>Prof. A. Thomson, M.D., F.R.S.</td>
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<td>1839, Aug. 15</td>
<td>Plymouth</td>
<td>W. Spottiswoode, M.A., F.R.S.</td>
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<td>1839, Aug. 24</td>
<td>Dublin</td>
<td>Prof. G. J. Allman, M.D., F.R.S.</td>
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<td>1839, Aug. 20</td>
<td>Sheffield</td>
<td>A. C. Ramsay, LL.D., F.R.S.</td>
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<td>1839, Aug. 25</td>
<td>Swansea</td>
<td>Sir Thomas Lubbock, F.R.S.</td>
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<td>1839, Aug. 31</td>
<td>York</td>
<td>Dr. C. W. Siemens, F.R.S.</td>
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<td>1839, Aug. 23</td>
<td>Southampton</td>
<td>Prof. A. Cayley, D.C.L., F.R.S.</td>
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<td>1839, Aug. 19</td>
<td>Southport</td>
<td>Prof. Lord Rayleigh, F.R.S.</td>
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<td>1839, Aug. 27</td>
<td>Montpelier</td>
<td>Sir Lyon Playfair, K.C.B., F.R.S.</td>
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<td>1839, Aug. 5</td>
<td>Aberdeen</td>
<td>Sir J. W. Dawson, C.M.G., F.R.S.</td>
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<td>1839, Aug. 3</td>
<td>Birmingham</td>
<td>Sir H. E. Roscoe, D.C.L., F.R.S.</td>
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<td>Manchester</td>
<td>Sir F. J. Bramwell, F.R.S.</td>
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<td>1839, Sept. 5</td>
<td>Bath</td>
<td>Prof. W. H. Flower, C.B., F.R.S.</td>
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<td>1839, Sept. 11</td>
<td>Newcastle-on-Tyne</td>
<td>Sir F. Abel, C.B., F.R.S.</td>
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<td>1839, Sept. 9</td>
<td>Leeds</td>
<td>Dr. W. Huggins, F.R.S.</td>
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<td>1839, Aug. 19</td>
<td>Cardiff</td>
<td>Sir A. Geikie, LL.D., F.R.S.</td>
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<td>1839, Aug. 3</td>
<td>Edinburgh</td>
<td>Prof. J. S. Burdon Sanderson, F.R.S.</td>
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<td>1839, Aug. 13</td>
<td>Nottingham</td>
<td>The Marquis of Salisbury, K.G., F.R.S.</td>
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<td>1839, Aug. 15</td>
<td>Ipswich</td>
<td>Sir Joseph Lister, Bart., F.R.S.</td>
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<td>1839, Aug. 3</td>
<td>Liverpool</td>
<td>Sir John Evans, K.C.B., F.R.S.</td>
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<td>1839, Aug. 17</td>
<td>Toronto</td>
<td>Sir W. Crookes, F.R.S.</td>
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<td>1839, Aug. 7</td>
<td>Bristol</td>
<td>Sir Michael Foster, K.C.B., Sec. R.S.</td>
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* Ladies were not admitted by purchased tickets until 1843.  | Tickets of Admission to Sections only.

[Continued on p. xiv.]
<table>
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‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

[Continued on p. xv.]
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</table>

1 Including 848 Members of the South African Association.
2 Including 139 Members of the American Association.
3 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.
4 Including Students’ Tickets, ros.
5 Including Exhibitioners granted tickets without charge.
6 Including grants from the Caird Fund in this and subsequent years.
7 Including Foreign Guests, Exhibitioners, and others.
### Annual Meetings

#### Old Annual Members

<table>
<thead>
<tr>
<th>New Annual Members</th>
<th>Associates</th>
<th>Ladies</th>
<th>Foreigners</th>
<th>Total</th>
<th>Amount received for Tickets</th>
<th>Sums paid on account of Grants for Scientific Purposes</th>
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<tbody>
<tr>
<td>297</td>
<td></td>
<td>801</td>
<td>482</td>
<td>9</td>
<td>1915</td>
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<td>374</td>
<td>131</td>
<td>794</td>
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<td>314</td>
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<td>6</td>
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<td>536</td>
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<td>61</td>
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<td>251</td>
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#### Young Annual Regular Members

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<thead>
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<th>Monthly Meeting Report</th>
<th>Meeting only</th>
<th>Transferable Tickets</th>
<th>Students' Tickets</th>
<th>Complimentary</th>
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<td>76</td>
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<td>1096</td>
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<td>200</td>
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</tbody>
</table>

- *The Bournemouth Fund for Research, initiated by Sir C. Parsons, enabled grants on account of scientific purposes to be maintained.
- *Including grants from the Caid Gift for research in radioactivity in this and subsequent years to 1926.
- *Subscriptions paid in Canada were $5 for Meeting only and others pro rata; there was some gain on exchange.
- *Including 413 tickets for certain meetings, issued at $5s. to London County Council school-teachers.
- *For nine months ending March 31, 1933.
- *Sir William B. Hardy, F.R.S., who became President on January 1, 1934, died on January 23.
NARRATIVE OF THE NOTTINGHAM MEETING.

On Wednesday, September 1, at 8.30 p.m., the Inaugural General Meeting was held in the Albert Hall, Derby Road, when the Rt. Worshipful the Lord Mayor of Nottingham (Councillor A. E. Purser) welcomed the Association to Nottingham. The President of the Association, Prof. Sir Edward B. Poulton, F.R.S., delivered an address (for which see p. 1) entitled The History of Evolutionary Thought, as recorded at Meetings of the British Association.

Evening Discourses were delivered to the Members as follows:

(1) Friday, September 3, Great Hall, University College, at 8.30 p.m. Dr. R. E. Slade: Grass and the National Food Supply. (See p. 457.)

(2) Monday, September 6, Albert Hall, Derby Road, at 8.30 p.m., Prof. J. Gray, F.R.S.: The Mentality of Fishes.

Public lectures were delivered as follows:

LINCOLN.
Mr. R. Kay Gresswell: Rivers and Waterways. At the New Co-operative Hall, Lincoln, on Friday, September 3, at 8 p.m.

MANSFIELD.
Prof. J. Walton: Coal and its Origin. At the Lecture Theatre, Technical College, Mansfield, on Friday, September 3, at 7.30 p.m.

NOTTINGHAM.
Prof. H. Hartridge, F.R.S.: Illusions of Colour. At the Hippodrome Picture Theatre, Theatre Square, Nottingham, on Sunday, September 5, at 8.15 p.m.

DERBY.
Sir Gilbert Walker, C.S.I., F.R.S.: The Mechanics of Sport. At the Guildhall, Derby, on Monday, September 6, at 8 p.m.

NEWARK-ON-TRENT.
Mr. T. M. Herbert: The Transport of Food. At the County Technical College, Newark-on-Trent, on Monday, September 6, at 7.30 p.m.

LONG EATON.
Dr. J. E. R. Constable: Science in Every-day Life. At the County Secondary School, Long Eaton, on Tuesday, September 7, at 8 p.m.

A lecture to school children was given by Dr. Alexander Wood on Noise, at the Cottesmore School Hall, Derby Road, Nottingham, on Friday, September 3, at 2.30 p.m.
A summary of Sectional Transactions on September 2–8 will be found on pp. 333 and following. All Sections had their meeting-rooms, together with the Reception Room, in the University College or immediately adjacent thereto.

The Lord Mayor and Corporation of the City of Nottingham entertained members of the Association at a Reception in the Castle Museum on Thursday evening, September 2.

A Garden Party was given by the Headmaster of Repton School, at the School, on Monday, September 6.

A Garden Party was given by the Council of University College, Nottingham, in the College, on Tuesday, September 7.

On Saturday, September 4, general excursions were arranged:
(1) To Southwell, Newark, Lincoln (where the Mayor of Lincoln entertained the party).
(2) To Sherwood Forest and the Dukeries.
(3) Through Derbyshire (His Grace the Duke of Devonshire receiving the party at Chatsworth).

Other excursions and visits devoted to the interests of special Sections are mentioned among the Sectional Transactions in later pages.

A special service was held at St. Mary’s Parish Church on Sunday morning, September 5, when the preacher was the Vicar (the Rt. Rev. Neville S. Talbot, D.D., M.C.). Special services were held in other places of worship also.

At the final meeting of the General Committee, on Wednesday, September 8, it was resolved:

That the British Association places on record its warm thanks for the reception accorded to it by the City of Nottingham. The generous cooperation of the City Council and the thorough preparations made by the local officers have been deeply appreciated. The Association also extends most cordial thanks to the commercial, industrial, and educational institutions in Nottingham and the neighbourhood, which have so generously provided accommodation and facilities for meetings, excursions, and visits. A special expression of gratitude is offered to the authorities of the University College, who have provided the most convenient possible arrangements for the Reception Room and for the sectional and other meetings.

H.M. King George VI, Patron of the Association.

I.—His Majesty The King has been graciously pleased to confer his Patronage upon the Association.

II.—The following Address has been forwarded to His Majesty:

To The King's Most Excellent Majesty.

May it please Your Majesty,

We, the President and Council of the British Association for the Advancement of Science, humbly submit to Your Majesty and to Her Majesty The Queen our heartfelt good wishes on Your Accession. We trust that Your Majesty's Reign may mark an era of peaceful progress, shared by Your Majesty's peoples with mankind at large; and that to such progress Science may contribute its full share. To assure that end will be the constant aim of the Association, inspired thereto by the Patronage which Your Majesty has been graciously pleased to confer upon it.

III.—The President, Prof. Sir Edward Poulton, F.R.S., accepted an invitation to represent the Association at the ceremony of Their Majesties' Coronation in Westminster Abbey.

Obituary.

IV.—The Council have had to deplore the loss by death of the following office-bearers and supporters:

Prof. H. E. Armstrong, F.R.S.
Prof. A. W. Borthwick
Prof. E. B. Elliot, F.R.S.
Prof. G. Forbes, F.R.S.
Prof. D. F. Fraser-Harris
Sir Albert Kitson, C.M.G.
Prof. T. M. Lowry, F.R.S.
Dr. F. S. Macaulay, F.R.S.
Prof. J. A. MacWilliam

Sir D. Orme Masson, F.R.S.
Hon. W. Pember Reeves
Mr. J. H. Reynolds
Rt. Hon. Lord Rothschild, F.R.S.
Prof. Sir G. Elliot Smith, F.R.S.
Prof. W. J. Sollas, F.R.S.
Mr. W. Taylor, F.R.S.
Dr. Max Weber
Prof. Sydney Young, F.R.S.

Representation.

V.—Representatives of the Association have been appointed as follows:

Coronation of Their Majesties The King and Queen, Westminster Abbey, May 12

Prof. Sir E. B. Poulton, F.R.S., President.
British National Committee on Geodesy and Geophysics  
British National Committee on Geography  
Joint Committee of Anthropological Research and Teaching  
Publications Committee of the Royal Society on bibliographical reference  
Association Française pour l'Avancement des Sciences, Paris, May 18-22  
American Association for the Advancement of Science, 100th Meeting, June 21-26  
Association Française pour l'Avancement des Sciences, Paris, July 24-27  
Buchan Club, Jubilee Meeting, Peterhead, August 7  

Dr. H. Jeffreys, F.R.S.  
Prof. R. N. Rudmose-Brown.  
Dr. H. S. Harrison.  
The Secretary.  
Lt.-Col. W. Campbell Smith, T.D., M.C.  
Prof. N. V. Sidgwick, C.B.E., F.R.S.  
Prof. C. S. Spearman, F.R.S.  
Prof. J. Ritchie.

Professor Sidgwick accepted the invitation of the American Association to deliver the Hector Maiben Lecture at the above meeting.

**Resolutions and Recommendations.**

VI.—Resolutions and recommendations, referred by the General Committee to the Council for consideration, and, if desirable, for action, were dealt with as follows. The resolutions will be found in the Report for 1936, p. lxi.

*(a)* The following resolution, received from Section B (Chemistry) at the Blackpool Meeting, was considered at a special meeting of the Council:—

The members of the Committee of Section B, in agreement with the views expressed in their President’s address regarding science and warfare, request the General Committee to secure all possible publicity for the following: (1) The extent to which Chemistry is applied for beneficent purposes in connection with the industry of the British nation and the health of its citizens, is enormously greater than the scope of its employment for purposes of warfare. (2) Whilst the individual must remain free to determine his own action in relation to national defence, chemists as a body view with grave concern the increasing use of science for destructive ends.

After full consideration, and examination of the wording as affecting all Sections, it was resolved by a majority that no action be taken.

*(b)* Following upon a resolution of Section C (Geology), the Council considered the report of a Committee of that Section on the teaching of geology in schools, approved its circulation to authorities considering syllabuses about the close of the year 1936, and appointed a committee, under the chairmanship of Prof. W. W. Watts, F.R.S., to consider and deal with any further distribution.
(c) At the request of the Council, the Geological Society agreed to forward to the International Geological Congress the suggestion that recent evidence of climatic change should be discussed at the Congress. (Resolution of Section C, Geology.)

(d) A resolution from Section G (Engineering), referring to legal procedure in connection with patent actions, was not adopted.

(e) The Councils for the Preservation of Rural England, Scotland, and Wales were informed that the subject of rubbish dumping had been brought before the Conference of Delegates of Corresponding Societies, and that the Council would be pleased to offer the collaboration of the Association, through its Corresponding Societies, if it should appear to the Councils addressed that such collaboration would be useful. (Resolution of the Conference of Delegates of Corresponding Societies.)

(f) The following resolution was received from the Conference of Delegates of Corresponding Societies:—

To request the Council of the British Association to support the Council for the Preservation of Rural England in its endeavour to stimulate His Majesty's Government to consider and take action upon the report of the Government Committee on National Parks.

This resolution was adopted by the Council, and the Council for the Preservation of Rural England were informed accordingly.

FINANCE.

VII.—The Council have received reports from the General Treasurer throughout the year. His account has been audited and is presented to the General Committee.

The Council made the following grants from funds under their control:—

From the Caird Fund.

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<thead>
<tr>
<th>Committee on Seismology</th>
<th>£150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committee on Mathematical Tables</td>
<td>£150</td>
</tr>
<tr>
<td>Committee on Zoological Record</td>
<td>£50</td>
</tr>
<tr>
<td>Committee on Plymouth Marine Laboratory</td>
<td>£50</td>
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From the Bernard Hobson Fund.

<table>
<thead>
<tr>
<th>Committee on Brundon Bone-bed</th>
<th>£25</th>
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</thead>
<tbody>
<tr>
<td>Committee on Reptile-bearing Oolite of Stow-on-the-Wold</td>
<td>£25</td>
</tr>
<tr>
<td>Committee on Thermal Conductivities of Rocks: such part of the grant of £25 as the remaining income of the fund will allow.</td>
<td></td>
</tr>
</tbody>
</table>

From the Leicester and Leicestershire Fund.

<table>
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<th>Committee on Perseveration</th>
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</thead>
<tbody>
<tr>
<td>Committee on Routine Manual Factor in Mechanical Ability</td>
<td>£30</td>
</tr>
</tbody>
</table>
A maintenance grant of £30 was made from the Leicester and Leicestershire Fund to Mr. H. O. Chaplin, of University College, Leicester, to enable him to carry on research into the rôle of the resonating hydrogen atom as a causative factor in molecular association.

Following upon the resolution reported last year, to use the donation of £105 from the Local Committee for the Norwich Meeting, 1935, for grants for researches of special interest in East Anglia, the following grants were made from that fund:

- To the Norfolk Research Committee, for excavation of West Rudham tumulus £30
- To the same, for investigation of post-glacial deposits of East Norfolk £40
- To Mr. A. S. Watt, for investigation of cyclic phenomena in the vegetation of Breckland £30

VIII.—A final payment of £341 has been received under the Herbert Spencer Bequest, bringing the total to £1241.

As reported last year, the Council adopted a proposal, supported by the Down House Committee, that the sum of £500 should be earmarked to meet temporarily the cost of repairs and other works on the Down House property, and the provision of facilities for scientific work there as occasion should arise. This matter is referred to in the Report of the Down House Committee, annexed to this present Report of the Council.

The Council empowered the General Treasurer to expend from the Spencer Bequest a sum not exceeding £100, if necessary, by way of grant in aid of travelling expenses for a representative of the Association to attend the Denver Meeting of the American Association, June 21–26, 1937 (see above, § V).

It may be recorded here that the terms of the bequest, while leaving the Council a wide discretion as to the disposal of the money 'for the work or objects or purposes' of the Association, prescribes that no part of it 'shall be utilised in any way for purpose of endowment but on the contrary shall within the period of five years from the date of payment . . . be expended.' The date of receipt of the final payment was November 3, 1936.

The Council, on receipt of the final payment, forwarded an expression of their thanks to the trustees under the will.

President (1938), General Officers, General Committee, and Council.

IX.—The Council's nomination to the Presidency of the Association for the year 1938 (Cambridge Meeting) will be announced to the General Committee at the Nottingham Meeting.

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

General Treasurer, Prof. P. G. H. Boswell, F.R.S.
General Secretaries, Prof. F. T. Brooks, F.R.S., Prof. Allan Ferguson.
XI. General Committee.—The following have been admitted as members of the General Committee, mainly on the nomination of Organising Sectional Committees under Regulation 1:

Dr. D. A. Allan  
Lady Briscoe  
Dr. H. O. Bull  
Dr. O. M. B. Bulman  
Prof. D. Burns  
Mr. L. R. Cox  
Miss E. Dix  
Prof. T. H. Easterfield  
Prof. H. Hartridge, F.R.S.  
Mr. M. A. C. Hinton, F.R.S.  
Mr. K. P. Oakley  
Mr. S. I. Tomkeieff  
Mr. L. H. Tonks  
Dr. C. B. Williams

XII. Council.—The retiring Ordinary Members of the Council are: Sir Henry Dale, F.R.S., Prof. R. B. Forrester, Dr. H. S. Harrison, Dr. J. S. Huxley, Prof. R. Robinson, F.R.S.

The Council have nominated as new members Prof. H. J. Fleure, F.R.S., Prof. T. S. Moore and Dr. R. S. Whipple; leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of Ordinary Members nominated is as follows:

Dr. F. W. Aston, F.R.S.  
Prof. F. Aveling  
Prof. F. Balfour-Browne  
Sir T. Hudson Beare  
Prof. R. N. Rudmose Brown  
Dr. W. T. Calman, C.B., F.R.S.  
Prof. F. Debenham  
Prof. W. G. Fearsides, F.R.S.  
Prof. H. J. Fleure, F.R.S.  
H. M. Hallsworth, C.B.E.  
Prof. A. V. Hill, Sec.R.S.  
Prof. T. G. Hill  
Prof. G. W. O. Howe  
Prof. T. S. Moore  
Lt.-Col. W. Campbell Smith  
Dr. C. Tierney  
Dr. W. W. Vaughan, M.V.O.  
Dr. J. A. Venn  
Prof. Sir Gilbert Walker, C.S.I., F.R.S.  
Prof. F. E. Weiss, F.R.S.  
Dr. R. S. Whipple  
J. S. Wilson

FUTURE MEETINGS.

XIII.—The future places of meeting already determined by the General Committee are Cambridge (1938) and Dundee (1939). There have been received invitations for the Association to meet in Swansea in any convenient year, in Belfast in 1941 or any year nearly following, and in 1943 in Birmingham. No invitation definitely for the year 1940 has been received.

MISCELLANEA.

XIV. Visit to the Isle of Man.—This visit was paid by a representative party of members immediately after the Blackpool Meeting, 1936, and on its conclusion the Council forwarded a vote of thanks to the island authorities and individuals who had kindly collaborated in the arrangements.

XV. British Science Guild.—Under the arrangement proposed last year by the Council and adopted by the General Committee, the British Science Guild was incorporated into the Association as from November 30,
1936. In accordance with the agreement of incorporation a British Science Guild Committee has been appointed to continue arrangements for lectures already initiated by the Guild, and for any others of similar character which may be approved by the Council. The Council of the Guild appointed to this Committee Lady Lockyer, Commander L. C. Bernacchi, and Sir Richard Gregory, Bart., F.R.S.; and the Council of the Association appointed Prof. A. Ferguson, Sir Daniel Hall, K.C.B., F.R.S., and Dr. W. W. Vaughan.

The first of the lectures arranged by the Association under the above scheme was the Alexander Pedler lecture, given in Leicester on May 3, in co-operation with the University College in that city, by Prof. Allan Ferguson.

The first Norman Lockyer lecture to be so arranged will be given by Dr. R. E. Mortimer Wheeler in the Goldsmiths' Hall, London, by kind permission of the Goldsmiths' Company, on November 24.

XVI. Radford Mather Lectures.—The first of the triennial lectures under the foundation of Mr. G. Radford Mather will be given by the Rt. Hon. J. Ramsay MacDonald, P.C., M.P., F.R.S., in the Royal Institution, London, by kind permission of the managers, on October 22.

XVII. Indian Science Congress Association.—The Council recorded their great satisfaction that Lord Rutherford had accepted the presidency of the joint Congress of the Indian Science Congress Association and a delegation from the British Association in 1938. A committee of the Council have been actively engaged in arrangements for this delegation.

The Council recommend that inasmuch as it is important that the visit should be a marked success, a grant of £1,000 should be made from the funds of the Association to the India Fund.

XVIII. American Association for the Advancement of Science.—Following upon discussion and correspondence, a scheme has been proposed in order to facilitate the attendance of members of the American Association at meetings of the British Association and vice versa, and also the receipt of the publications of either association by members of the other.

XIX. Corporation Membership.—The Institution of Professional Civil Servants, and Messrs. Macmillan & Co., publishers, have been admitted to corporation membership of the Association.

XX. Armorial Bearings.—The Association has received a grant of armorial bearings from the College of Arms, the incidental costs being met by the gifts of an anonymous donor and of ex-Presidents of the Association. The blazon is as follows:—

Arms: Azure ten stars, two of six, four of five, and four of four points Argent (representing the constellation of Libra) over all a Balance Or.

Motto: Sed Omnia Disposuisti.

The motto is taken from Wisdom of Solomon, ii, 20 (‘But Thou hast ordered all things in measure and number and weight’).

XXI. L’Association française pour l’avancement des Sciences.—The Council had the pleasure of entertaining at Down House, on July 29,
a party of representatives of L’Association française visiting England, and including M. Maurain, the President, Mme. Maurain, Dr. Verne, the Secretary-general, and Mme. Verne. The party was received by Sir Arthur Keith, F.R.S., ex-President (in the absence of the President, Sir Edward Poulton, F.R.S.), and by members of the Council and others.

The medal of the French Association was presented by M. Maurain to the British Association, and copies thereof to the General Secretaries, Lt.-Col. W. Campbell Smith, and the Secretary.

XXII. Amendment of Statutes.—In view of the occupation of premises by the Association at Burlington House and at Down House, the Council recommend that Statute VI, 5, where now reading ‘The Secretary shall be charged . . . (ii) with the control and direction of the office and of all persons therein employed,’ be amended to read ‘The Secretary shall be charged . . . (ii) with the control and supervision of all persons in the employment of the Association and of premises in its occupation.’

DOWN HOUSE.

XXIII.—The following report for the year 1936–37 has been received from the Down House Committee:

The number of visitors to Down House during the year ending June 6, 1937, has been 6,148, compared with 7,022 in 1935–6, and an average of 7,242 per year for five years in 1931–6.

The Committee have expressed their gratitude to Prof. F. T. Brooks, F.R.S., who, on succeeding to the chair of botany in the University of Cambridge, continued the loan of Darwin’s library to Down House. This loan was originally granted by Prof. Brooks’ predecessor, Sir Albert Seward, F.R.S., the possession of the library having been vested, under the will of Sir Francis Darwin, in the professor of botany in Cambridge for the time being.

A fine plaster model of a seated figure of Darwin has been presented to the house by Mr. J. Peacock. Enquiry has not revealed the name of the artist.

Lady Avebury has presented to Down House twelve letters from Darwin to John Lubbock (afterwards Lord Avebury), and one from Francis Darwin to Lubbock.

The Committee reported last year that they had obtained an architect’s report on the structural condition of the house and other buildings on the estate. Acting upon this report, the Committee have undertaken certain repairs (mainly of the cottages and old farm buildings); for the rest, the report provides the Committee with some guidance as to works which may be expected to become necessary in the course of the next few years. The Committee deeply appreciate the action of the Council in placing at the disposal of the General Treasurer the sum of £500 from the Herbert Spencer bequest towards the cost of repairs, renewals, and the provision of scientific appliances if required.

The Committee have enquired into the question of carrying on scientific observations at Down, and are grateful to Sir George Simpson, C.B., F.R.S., Dr. F. J. W. Whipple, and Dr. R. G. Hatton, for their personal interest in this matter. Various possibilities have been considered, but, with the exception of the establishment of a standard rain-gauge, no line of enquiry which would be both possible and justifiable on the ground of expense of
appliances has as yet been proposed. On the suggestion of Miss Saunders, of Goldsmiths' College, the Committee asked a number of heads of departments in London colleges whether the fitting-up of the old farm buildings for laboratory purposes would be likely to be of use to students engaged in field-work in the district or for any other such purpose; but the response was not such as to justify the Committee in pursuing this possibility further for the present.

The following financial statement shows income and expenditure on account of Down House for the years ending March 31, 1936 and 1937:—

<table>
<thead>
<tr>
<th>Income</th>
<th>1936-37</th>
<th>Corresponding figures, 1935-36</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>£ s. d.</td>
<td>£ s. d.</td>
</tr>
<tr>
<td>By Rents receivable</td>
<td>141 0 0</td>
<td>141 0 0</td>
</tr>
<tr>
<td>&quot; Income Tax recovered</td>
<td>168 1 6</td>
<td>168 1 6</td>
</tr>
<tr>
<td>&quot; Interest and Dividends</td>
<td>817 2 0</td>
<td>826 8 6</td>
</tr>
<tr>
<td>&quot; Donations</td>
<td>3 17 1</td>
<td>16 7 2</td>
</tr>
<tr>
<td>&quot; Sale of Postcards and Catalogues</td>
<td>23 8 4</td>
<td>25 12 7</td>
</tr>
<tr>
<td>&quot; Pilgrim Trust Grant</td>
<td>150 0 0</td>
<td>150 0 0</td>
</tr>
<tr>
<td>&quot; Instalment of Grant from Herbert Spencer Bequest</td>
<td>132 3 4</td>
<td>—</td>
</tr>
<tr>
<td><strong>Total Income</strong></td>
<td><strong>£1,435 12 3</strong></td>
<td><strong>£1,327 9 9</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>1936-37</th>
<th>Corresponding figures, 1935-36</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>£ s. d.</td>
<td>£ s. d.</td>
</tr>
<tr>
<td>To Wages of Staff</td>
<td>803 19 7</td>
<td>783 15 10</td>
</tr>
<tr>
<td>&quot; Rates, Insurance, etc.</td>
<td>69 5 6</td>
<td>66 5 8</td>
</tr>
<tr>
<td>&quot; Coal, coke, etc.</td>
<td>138 14 8</td>
<td>86 18 6</td>
</tr>
<tr>
<td>&quot; Lighting and Drainage (including oil and petrol)</td>
<td>79 4 11</td>
<td>76 3 10</td>
</tr>
<tr>
<td>&quot; Water</td>
<td>15 7 1</td>
<td>15 16 8</td>
</tr>
<tr>
<td>&quot; Surveyor's Fee</td>
<td>—</td>
<td>5 5 0</td>
</tr>
<tr>
<td>&quot; Rain-gauge</td>
<td>1 7 8</td>
<td>—</td>
</tr>
<tr>
<td>&quot; Repairs and Renewals</td>
<td>159 2 4</td>
<td>74 13 9</td>
</tr>
<tr>
<td>&quot; Garden and Land: Materials and Maintenance</td>
<td>45 19 8</td>
<td>72 12 1</td>
</tr>
<tr>
<td>&quot; Donations to Village Institutions</td>
<td>5 5 0</td>
<td>5 5 0</td>
</tr>
<tr>
<td>&quot; Household Requisites, etc.</td>
<td>15 18 10</td>
<td>15 19 4</td>
</tr>
<tr>
<td>&quot; Transport and Carriage</td>
<td>1 16 6</td>
<td>2 13 11</td>
</tr>
<tr>
<td>&quot; Accountants' Fees</td>
<td>8 8 0</td>
<td>18 18 1</td>
</tr>
<tr>
<td>&quot; Printing, Postages, Telephone and Stationery</td>
<td>35 7 5</td>
<td>39 0 0</td>
</tr>
<tr>
<td>&quot; Balance, being excess of income over expenditure for the year, transferred to Suspense Account</td>
<td>55 15 1</td>
<td>64 2 1</td>
</tr>
<tr>
<td><strong>Total Expenditure</strong></td>
<td><strong>£1,435 12 3</strong></td>
<td><strong>£1,327 9 9</strong></td>
</tr>
</tbody>
</table>
GENERAL TREASURER’S REPORT, 1936-37

In 1932 the then General Treasurer, Sir Josiah Stamp, made a report to the Council in which he recommended the establishment of a Contingency Fund to be regarded as ‘an insurance against small or very unprofitable meetings,’ in order to enable grants in aid of research to be maintained at a fairly constant figure, and not made ‘on a year-to-year consideration of available balances.’ The Council, on this report, recommended to the General Committee, and the General Committee approved, a proposal that for a period of five years ‘not more than £400 should be spent annually from general funds on grants for research, and that an annual sum of £500 should be placed to a contingency fund.’

The five-years’ period is now finished, so that it is my duty to take stock of the outcome of these proposals.

In each of the five years there has been a balance, on general funds, of income over expenditure, but in no year has this reached £500. The actual figures are as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1933</td>
<td>375</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1934</td>
<td>394</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>1935</td>
<td>454</td>
<td>8</td>
<td>3½</td>
</tr>
<tr>
<td>1936</td>
<td>273</td>
<td>1</td>
<td>3½</td>
</tr>
<tr>
<td>1937</td>
<td>443</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>1,940</td>
<td>17</td>
<td>1</td>
</tr>
</tbody>
</table>

There is also a debtor sum due this year, although not forthcoming until next year, which should properly fall into the Contingency Fund, bringing it up to £2,000 or a little more. It was not thought necessary, in practice, to credit more than these available balances to the Contingency Fund each year, since this would merely have created artificial adverse balances on the general accounts of receipts and expenditure.

As for the resolution that ‘not more than £400 should be spent annually from general funds on grants for research,’ the average annual expenditure under this head has been approximately £323, on account of grants made being unclaimed.

As I am reviewing the results of the financial report of 1932, I should perhaps recall that the Council then expressed the view that ‘the true function of the Association, in making grants to research committees, is the initiation of particular pieces of research rather than their quasi-permanent endowment.’ The General Committee adopted this view, with the proviso that it ‘should not be held to preclude [quasi-permanent] grants to institutions at which successive researches are to be carried on under research committees of the Association.’ It does not appear that the destination of grants has been materially affected by this expression
of policy. A chart which I have caused to be prepared shows that from 1919 (and in fact earlier) initiation rather than quasi-permanent endowment was actually the object of the larger proportion of our grants; but in 1931 the sum devoted to quasi-permanent endowment for the first time exceeded that of other grants, and this practice has continued each year since that date. There seems to be a good case for separate endowment of such quasi-permanent research committees, for they are undoubtedly doing excellent work.

I have now proposed, and the Council has recommended, that the Contingency Fund should be maintained at a sum of about £2,000, except in any year when receipts should be abnormally low, and, further, that inasmuch as the existing Contingency Fund is earmarked for grants in aid of research, any excess of income over expenditure on general account should be used for the creation of a second fund for contingencies not connected with such grants.

The Herbert Spencer Trust was wound up during the past year, and the Spencer Bequest to the Association amounted in aggregate to £1,241, as stated in the Report of the Council to the General Committee, par. VIII. In that report it is indicated that a sum of £500 has been definitely allocated, and the accounts herewith show that a part has been spent, for purposes connected with Down House, while a sum of £100 was voted contingently for another purpose during the ensuing financial year. The will prescribed the expenditure of the whole bequest within five years of the winding-up of the trust, that is to say, by November 1941. The purposes for which the bequest may be expended give the Council a wide discretion, and for the moment I do not propose to make any definite recommendation as to the disposal of the balance.

On the incorporation of the British Science Guild into the British Association, a capital sum of £3,431 was handed over to the Association, and will yield an annual income of about £100. Life Fellows of the Guild were admitted to life membership of the Association without further payment; but life members of the Guild were offered life membership of the Association on payment of the difference of fee (£5 10s.), with the result that our life membership fund has been augmented by the sum of £99. We assume the maintenance of the Norman Lockyer and Alexander Pedler Lectures, which were founded by the Guild; and the fees and other charges in connection with these, excluding printing, are estimated to amount to about £35.

Lastly, I have gratefully to acknowledge the gift of £250 from Mr. G. Radford Mather, a life member since 1901, for the purpose of establishing a Triennial Lecture on Recent Advances in Science and their relation to the Welfare of the Community.

P. G. H. Boswell,
General Treasurer.
**GENERAL TREASURER’S ACCOUNT**

**Balance Sheet,**

### LIABILITIES

<table>
<thead>
<tr>
<th>General Purposes:</th>
<th>£ s. d.</th>
<th>£ s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sundry Creditors</td>
<td>169 12 6</td>
<td></td>
</tr>
<tr>
<td>Hon. Sir Charles Parsons’ gift (£10,000) and legacy (£2,000)</td>
<td>12,000 0 0</td>
<td></td>
</tr>
<tr>
<td>The late Sir Alfred Ewing’s legacy</td>
<td>500 0 0</td>
<td></td>
</tr>
<tr>
<td>British Science Guild: Capital Fund</td>
<td>3,431 9 1</td>
<td></td>
</tr>
<tr>
<td>Bequest of Jakoff Prelooker</td>
<td>10 0 0</td>
<td></td>
</tr>
</tbody>
</table>

**Yarrow Fund**

- As per last Account: £5,115 6 4
- Less Transferred to Income and Expenditure Account under terms of the gift: 370 10 3

**Life and Corporate Compositions**

- As per last Account: 2,891 2 2
- Add Received during year: 277 10 0

**Contingency Fund**

- As per last Account: 1,497 7 6
- Add Amount transferred from Income and Expenditure Account: 443 9 7

**Accumulated Fund**

- 42,423 15 11

**Special Purposes:**

**Caird Fund**

- Balance at 1st April, 1936: 9,790 6 11
- Add Excess of Income over Expenditure for the year: 1 8 11

**Mathematical Tables Fund**

- Balance at 1st April, 1936: 68 14 7
- Receipts from Sales: 75 11 8

**Cunningham Bequest Fund**

- Balance at 1st April, 1936: 1,354 5 10
- Add Excess of Income over Expenditure for the year: 41 4 0

**Toronto University Presentation Fund**

- Capital: 178 11 4
- Revenue: 4 7 6

**Carried forward**: 53,938 6 8
31st March, 1937

<table>
<thead>
<tr>
<th>ASSETS</th>
<th>£  s.  d.</th>
<th>£  s.  d.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GENERAL PURPOSES:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investments as scheduled with Income and Expenditure Account, No. 1</td>
<td>41,961</td>
<td>12 1</td>
</tr>
<tr>
<td>Sundry debtors and payments in advance</td>
<td>94</td>
<td>9 8</td>
</tr>
<tr>
<td>Cash at bank</td>
<td>347</td>
<td>7 3</td>
</tr>
<tr>
<td>Cash in hand</td>
<td>20</td>
<td>6 11</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>38,837</strong></td>
<td><strong>10 11</strong></td>
</tr>
</tbody>
</table>

**SPECIAL PURPOSES:**

**Caird Fund Account**
- Investments (see Income and Expenditure Account, No. 2) | 9,582 | 16 3 |
- Cash at bank | 208 | 19 7 |
- **Total:** | **9,791** | **15 10** |

**Mathematical Tables Fund Account**
- Cash at bank | 70 | 19 7 |
- Sundry debtors | 73 | 6 8 |
- **Total:** | **144** | **6 3** |

**Cunningham Bequest Fund Account**
- Investments (see Income and Expenditure Account, No. 3) | 1,305 | 7 2 |
- Cash at bank | 90 | 2 8 |
- **Total:** | **1,395** | **9 10** |

**Toronto University Presentation Fund Account**
- Investments (see Income and Expenditure Account, No. 4) | 178 | 11 4 |
- Cash at bank | 4 | 7 6 |
- **Total:** | **182** | **18 10** |

Carried forward | | 53,938 | 6 8 |
Balance Sheet,

**LIABILITIES (continued)**

<table>
<thead>
<tr>
<th></th>
<th>£</th>
<th>s.</th>
<th>d.</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brought forward</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bernard Hobson Fund</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Revenue—Balance per last Account</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Add Excess of Income over Expenditure for the year</strong></td>
<td></td>
<td></td>
<td></td>
<td>27</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>58</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>1,050</td>
<td>2</td>
<td>2</td>
<td></td>
<td>1,058</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Leicester and Leicestershire Fund, 1933</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Revenue—Balance per last Account</td>
<td></td>
<td></td>
<td></td>
<td>65</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td><strong>Less Excess of Expenditure over Income for the year</strong></td>
<td></td>
<td></td>
<td></td>
<td>23</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>1,065</td>
<td>8</td>
<td>4</td>
<td></td>
<td>1,042</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Herbert Spencer Bequest Fund</td>
<td></td>
<td></td>
<td></td>
<td>1241</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Less Amounts Expended during year</strong></td>
<td></td>
<td></td>
<td></td>
<td>133</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,107</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Norwich Fund, 1935</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>105</td>
<td>0</td>
</tr>
<tr>
<td>Radford Mather Lecture Fund</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>Indian Science Congress Delegation Fund</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subscriptions received to date</td>
<td></td>
<td></td>
<td></td>
<td>278</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Down House</td>
<td></td>
<td></td>
<td></td>
<td>20,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Endowment Fund</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Sundry Creditors and Credit Balances</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20,093</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Suspense Account</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance per last Account</td>
<td>24</td>
<td>18</td>
<td>8</td>
<td>80</td>
<td>13</td>
<td>9</td>
</tr>
</tbody>
</table>
| **Note.**—There are contingent Liabilities in respect of grants voted to Research Committees at Blackpool and by Council in 1936 but not claimed at 31st March, 1937, amounting to £579 7s. 6d. The amount which should, in accordance with Council's resolution, have been in the Contingency Fund at 31st March, 1937, was £2,375, but the surplus income available for this purpose has been insufficient by £434 2s. lid. to meet the full annual amounts transferable.

I have examined the foregoing Account with the Books and Vouchers and certify and the Investments, and the Bank have certified to me that they hold the

Approved.

**Auditors.**

Ezer Griffiths
R. S. Whipple
31st March, 1937 (continued)

<table>
<thead>
<tr>
<th>Corresponding Figures</th>
<th>£ s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>31st March, 1936.</td>
<td>1,030 2 2</td>
</tr>
<tr>
<td>31st March, 1937.</td>
<td>1,065 8 4</td>
</tr>
</tbody>
</table>

### ASSETS (continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brought forward</td>
<td>53,938</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

**Bernard Hobson Fund Account**
- Investments (see Income and Expenditure Account, No. 6) | 1,000 | 0  | 0  |
- Cash at bank                                                          | 58   | 1  | 3  |
- Total                                                                 | 1,058 | 1 | 3  |

**Leicester and Leicestershire Fund, 1933 Account**
- Investments (see Income and Expenditure Account, No. 6) | 1,000 | 0  | 0  |
- Cash at bank                                                          | 42   | 2  | 6  |
- Total                                                                 | 1,042 | 2 | 6  |

**Herbert Spencer Bequest Fund Account**
- Investments (see Income and Expenditure Account, No. 7) | 741   | 0  | 0  |
- Cash at bank                                                          | 366  | 9  | 0  |
- Total                                                                 | 1,107 | 9 | 0  |

**Norwich Fund, 1935 Account**
- (Income and Expenditure Account, No. 8) |        |    |    |
- Cash at bank                                                          | 105  | 0  | 0  |

**Radford Mather Lecture Fund Account**
- Investments (see Income and Expenditure Account, No. 9) | 250   | 0  | 0  |

**Indian Science Congress Delegation Fund Account**
- Cash at bank                                                          | 278  | 5  | 0  |

**Down House Account**
- Endowment Fund Investments (see Income and Expenditure Account, No. 10) | 20,000 | 0 | 0  |
- Cash at bank                                                          | 36   | 12 | 8  |
- Cash in hand                                                          | 7    | 9  | 11 |
- Sundry debtors and payments in advance                                | 22   | 6  | 9  |
- Stock of catalogues                                                   | 26   | 16 | 1  |
- Total                                                                | 20,935 | 5 | 5  |

\[ \text{\£77,872 9 10} \]

the same to be correct. I have also verified the Balance at the Bankers Deeds of Down House.

W. B. KEEN, Chartered Accountant.


4th June, 1937.
INCOME AND EXPENDITURE ACCOUNTS FOR THE YEAR ENDED 31ST MARCH, 1937.

No. 1. General Income and Expenditure

<table>
<thead>
<tr>
<th>Investments</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>£6,749 12s. 2d.</td>
<td>Consolidated 2½ per cent. Stock, at cost</td>
<td>5,142</td>
<td>3</td>
</tr>
<tr>
<td>£3,600 0s. 0d.</td>
<td>India 3 per cent. Stock, at cost</td>
<td>3,522</td>
<td>2</td>
</tr>
<tr>
<td>£879 14s. 9d.</td>
<td>Great Indian Peninsula Railway 'B' Annuity £43, at cost</td>
<td>827</td>
<td>15</td>
</tr>
<tr>
<td>£52 12s. 7d.</td>
<td>War Stock (Post Office Issue), at cost</td>
<td>54</td>
<td>5</td>
</tr>
<tr>
<td>£1,400 0s. 0d.</td>
<td>3¼ per cent. War Loan Loan, at cost</td>
<td>1,393</td>
<td>16</td>
</tr>
<tr>
<td>£8,044 16s. 1d.</td>
<td>3¼ per cent. War Loan Inscribed Stock, at cost</td>
<td>8,093</td>
<td>17</td>
</tr>
<tr>
<td>£12,994 16s. 6d.</td>
<td>4½ per cent. Conversion Stock, at cost</td>
<td>12,844</td>
<td>8</td>
</tr>
<tr>
<td>£6,368 15s. 7d.</td>
<td>3½ per cent. Conversion Stock, at cost</td>
<td>5,304</td>
<td>8</td>
</tr>
<tr>
<td>£94 7s. 0d.</td>
<td>4½ per cent. Conversion Stock (Post Office Issue), at cost</td>
<td>62</td>
<td>15</td>
</tr>
<tr>
<td>£4,184 18s. 2d.</td>
<td>3 per cent. Local Loans, at cost</td>
<td>3,073</td>
<td>12</td>
</tr>
<tr>
<td>£1,000 0s. 0d.</td>
<td>4 per cent. Funding Loan Bonds</td>
<td>1,170</td>
<td>0</td>
</tr>
<tr>
<td>£100 0s. 0d.</td>
<td>5 per cent. Great Western Railway Consolidated Pref. Stock</td>
<td>125</td>
<td>0</td>
</tr>
<tr>
<td>£900 0s. 0d.</td>
<td>Royal Mail Steam Packet Co. Ordinary Stock</td>
<td>nil</td>
<td></td>
</tr>
<tr>
<td>£345 16s. 8d.</td>
<td>3 per cent. London County Consolidated Stock</td>
<td>347</td>
<td>7</td>
</tr>
</tbody>
</table>

(Value of Stocks at 31/3/36, £43,533 2s. 1d.)

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 10 0</td>
<td>To Heat, Lighting and Power</td>
<td>37</td>
<td>10</td>
</tr>
<tr>
<td>68 2 1</td>
<td>Stationery</td>
<td>75</td>
<td>18</td>
</tr>
<tr>
<td>0 0 0</td>
<td>Rent</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>196 13 10½</td>
<td>Postages</td>
<td>188</td>
<td>14</td>
</tr>
<tr>
<td>142 13 2</td>
<td>Travelling expenses</td>
<td>131</td>
<td>8</td>
</tr>
<tr>
<td>75 14 11</td>
<td>Exhibitioners</td>
<td>64</td>
<td>13</td>
</tr>
<tr>
<td>35 14 5</td>
<td>Audit and Accountancy</td>
<td>35</td>
<td>14</td>
</tr>
</tbody>
</table>

Corresponding Figures
31st March, 1936.

<table>
<thead>
<tr>
<th>Income</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>By Old Annual Regular Members</td>
<td>82</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Annual members for Meeting only</td>
<td>1,333</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Annual members, with Report</td>
<td>469</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Transferable Tickets</td>
<td>156</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Student members</td>
<td>89</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

Cash at bank and in hand, £367 14s. 2d.
<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Royal Jubilee Decorations</td>
<td></td>
</tr>
<tr>
<td>(share of expenses)</td>
<td></td>
</tr>
<tr>
<td>Cost of optiscopes</td>
<td>-</td>
</tr>
<tr>
<td>Hire of episcopes</td>
<td>-</td>
</tr>
<tr>
<td>Cost of Fordigraph</td>
<td>26 10 0</td>
</tr>
<tr>
<td>Subscription to Parliamentary Science Committee</td>
<td>10 10 0</td>
</tr>
<tr>
<td>Legal charges re Pensions</td>
<td>28 2 0</td>
</tr>
<tr>
<td>General Expenses</td>
<td>252 11 11</td>
</tr>
<tr>
<td>Salaries and wages</td>
<td>1,932 9 0</td>
</tr>
<tr>
<td>Pension contributions</td>
<td>148 0 3</td>
</tr>
<tr>
<td>Printing, binding, etc.</td>
<td>1,151 10 11</td>
</tr>
<tr>
<td>Armorial Bearings : Expenditure to date</td>
<td>92 0 0</td>
</tr>
<tr>
<td>By Life compositions : amount transferred on expiry of membership</td>
<td>30 0 0</td>
</tr>
<tr>
<td>Sale of Publications</td>
<td>526 12 8</td>
</tr>
<tr>
<td>Advertisements in B.A. publications</td>
<td>246 2 4</td>
</tr>
<tr>
<td>Unexpended balances of grants, returned</td>
<td>6 0 0</td>
</tr>
<tr>
<td>Liverpool Exhibitioners</td>
<td>13 10 0</td>
</tr>
<tr>
<td>Donations towards cost of Armorial Bearings</td>
<td>92 1 0</td>
</tr>
<tr>
<td>Income Tax recovered</td>
<td>14 1 7</td>
</tr>
<tr>
<td>Interest on investments</td>
<td>1,529 10 6</td>
</tr>
<tr>
<td>Donations</td>
<td>1 3 6</td>
</tr>
<tr>
<td>Sir Alfred Yarrow's Gift : amount transferred</td>
<td>370 10 3</td>
</tr>
<tr>
<td>Carried forward</td>
<td>4,441 0 7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>264 6 2</td>
</tr>
<tr>
<td>4,960 1 10</td>
</tr>
</tbody>
</table>
No. 1. General Income and Expenditure (continued)

<table>
<thead>
<tr>
<th>Corresponding Figures</th>
<th>EXPENDITURE</th>
<th>Corresponding Figures</th>
<th>INCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>31st March, 1936.</td>
<td></td>
<td>31st March, 1936.</td>
<td></td>
</tr>
<tr>
<td>£ s. d.</td>
<td>£ s. d.</td>
<td>£ s. d.</td>
<td>£ s. d.</td>
</tr>
<tr>
<td><strong>To Publications</strong></td>
<td></td>
<td><strong>From sales transferred to</strong></td>
<td></td>
</tr>
<tr>
<td>66 3 7</td>
<td>Brought forward</td>
<td>4,960 1 10</td>
<td></td>
</tr>
<tr>
<td>24 16 5</td>
<td>Receipts from sales transferred to Mathematical Tables Fund</td>
<td>75 11 8</td>
<td></td>
</tr>
<tr>
<td>273 1 3½</td>
<td>Sir J. B. Harrison's Monograph: Receipts from sales transferred to Caird Fund</td>
<td>— — —</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&quot; Balance, being excess of income over expenditure for the year carried down</td>
<td>443 9 7</td>
<td></td>
</tr>
<tr>
<td><strong>To amount transferred to Contingency Fund</strong></td>
<td></td>
<td><strong>By balance brought down</strong></td>
<td></td>
</tr>
<tr>
<td>273 1 3½</td>
<td>£4,960 1 10</td>
<td>£443 9 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>£443 9 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>182 13 10</strong></td>
<td></td>
<td><strong>273 1 3½</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>£</th>
<th>£</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,441 0 7</td>
<td>4,960 1 10</td>
<td>443 9 7</td>
</tr>
</tbody>
</table>
No. 2. Caird Fund

The unconditional gift of Sir James Caird, in 1912, administered by the Council in accordance with recommendations adopted by the General Committee in 1913.

**INVESTMENTS:**

<table>
<thead>
<tr>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>£2,627</td>
<td>0s</td>
<td>10d</td>
</tr>
<tr>
<td>£2,100</td>
<td>0s</td>
<td>0d</td>
</tr>
<tr>
<td>£2,500</td>
<td>0s</td>
<td>0d</td>
</tr>
<tr>
<td>£2,000</td>
<td>0s</td>
<td>0d</td>
</tr>
</tbody>
</table>

(Value at 31/3/37, £9,306 7s. 4d.)

**EXPENDITURE**

<table>
<thead>
<tr>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Grants paid—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naples Table Committee</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Plymouth Marine Biological Station</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Zoological Record Committee</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Seismology Committee</td>
<td>150</td>
<td>0</td>
</tr>
<tr>
<td>Mathematical Tables Committee</td>
<td>63</td>
<td>15</td>
</tr>
</tbody>
</table>

Balance, being excess of Income over Expenditure for the year | 1 | 8 | 11 |

£365 | 4 | 5

Grants to research authorised, but not yet claimed at 31st March, 1937, amount to | £182 | 2 | 6

**INCOME**

<table>
<thead>
<tr>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>By Dividends and Interest</td>
<td>298</td>
<td>19</td>
</tr>
<tr>
<td>Income Tax recovered</td>
<td>61</td>
<td>1</td>
</tr>
<tr>
<td>Receipts from Sales of Sir J. B. Harrison's Monograph, transferred from Income and Expenditure Account</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Part Repayment of grant—Sir J. B. Harrison's Monograph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance, being excess of Expenditure over Income for the year</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

£365 | 4 | 5
No. 3. Cunningham Bequest

A legacy received by the Association in 1929 in trust under the will of Lt.-Col. A. J. C. Cunningham, for the preparation of new mathematical tables in the theory of numbers; administered by the Council.

<table>
<thead>
<tr>
<th>Investments</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>£1,187 6s. 10d. Consolidated 2½ per cent. Stock</td>
<td>653</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>£300 0r. 0d. Port of London 3½ per cent. Stock, 1949/99</td>
<td>216</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>£862 13s. 3d. Local Loans 3 per cent. Stock, at cost</td>
<td>436</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

(Value at 31/3/36, £2,148 12s. 5d.)

1,305 7 2

(Cash at bank, £90 2s. 8d.)

EXPENDITURE

<table>
<thead>
<tr>
<th>Fig.</th>
<th></th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 14 0</td>
<td>To Grants for the preparation of tables</td>
<td>24</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>257 11 6</td>
<td>&quot; Printing and Binding &quot;</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>—</td>
<td>&quot; Balance, being excess of income over expenditure for the year</td>
<td>41</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

£66 0 0

INCOME

| Corresponding | £ | s | d |
| Figures 31st March, 1936. | — | — | — |
| By Interest | 63 | 12 | 10 |
| " Income Tax recovered | 2 | 7 | 2 |
| " Profits on realisation of securities | — | — | — |
| " Excess of Expenditure over Income for the year | — | — | — |

£66 0 0

No. 4. Toronto University Presentation Fund

A fund voluntarily subscribed by members present at the Toronto Meeting in 1924. From the income a presentation of two bronze medals each year is made, together with presents of books, to selected students in pure and applied science respectively.

| Investment | £ | s | d |
|———|---|---|---|
| £175 3½ per cent. War Stock at cost | — | — | — |

(Value at 31/3/37, £178 11 4)

Corresponding Figures 31st March, 1936.

| £ | s | d |
|—— | --- | --- |
| £179 7s. 6d. | — | — |

(VALUE at 31/3/36, £186 16s. 3d.)

EXPENDITURE

| Fig. | £ | s | d |
|—— | --- | --- | --- |
| 6 2 6 | To awards | £6 | 2 | 6 |

£6 2 6

INCOME

| Corresponding | £ | s | d |
| Figures 31st March, 1936. | — | — | — |
| Cash at bank | £4 7s. 6d. | — | — |
| By Interest | £6 | 2 | 6 |
No. 5. Bernard Hobson Fund

The bequest of Mr. Bernard Hobson, 1933; the income to be applied to the promotion of geological research; administered by the Council.

**Investments:**

<table>
<thead>
<tr>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>0s. 0d.</td>
<td>4 per cent. Victory (Bearer) Bonds at cost</td>
</tr>
<tr>
<td>601</td>
<td>9s. 0d.</td>
<td>3 per cent. Local Loans at cost</td>
</tr>
</tbody>
</table>

(Value at 31/3/37, £1,000 0 0 £1,021 5s. 7d.)

Cash at bank, £58 1s. 3d.

### EXPENDITURE

<table>
<thead>
<tr>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 17 7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To Grants Paid</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7</td>
<td>17</td>
<td>5</td>
</tr>
</tbody>
</table>

"Balance, being excess of Income over Expenditure for the year | £ | s. | d. |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27</td>
<td>19</td>
<td>1</td>
</tr>
</tbody>
</table>

**INCOME**

<table>
<thead>
<tr>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 17 7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>By Interest</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unexpended balance of grant returned</td>
<td>31</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Income Tax Recovered</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

"Balance, being excess of Expenditure over Income for the year | £ | s. | d. |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>

Grants to research authorised, but not yet claimed at 31st March, 1937, amount to £50 0 0
**No. 6. Leicester and Leicestershire Fund, 1933**

The unexpended balance of the local fund for the Leicester Meeting in 1933, presented to the Association, the interest to be used in assisting by scholarships or otherwise students working for the advancement of science; administered by the Council.

<table>
<thead>
<tr>
<th>Investments</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>£487 2s. 11d. 3½ per cent. Conversion Stock at cost</td>
<td>500</td>
</tr>
<tr>
<td>£490 5s. 11d. 3½ per cent. War Stock at cost</td>
<td>500</td>
</tr>
</tbody>
</table>

(Value at 31/3/36, £1,025 16s. 4d.)

Cash at bank, £42 2s. 6d.

<table>
<thead>
<tr>
<th>EXPENDITURE</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 0 0</td>
<td></td>
<td></td>
<td>0 0</td>
</tr>
<tr>
<td>To Grant paid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31 4 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Balance, being excess of Income over Expenditure for the year</td>
<td>60 0 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Corresponding Figures</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>31st March, 1936</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INCOME</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>By Interest</td>
<td>34 4 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Unexpended balance of grant returned</td>
<td>2 10 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Balance, being excess of Expenditure over Income for the year</td>
<td>23 5 10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Grants to research authorised but not yet claimed at 31st March, 1937, amount to £40 0 0
No. 7. Herbert Spencer Bequest Fund

A gift from the late Herbert Spencer received during 1936, to be exhausted within 5 years and to be expended on purchase or enlargement of premises, books, apparatus or collections, or for furniture or repairs or equipment of travellers or donation of instruments of research, but in no way or degree for purposes of endowment.

<table>
<thead>
<tr>
<th>Investments</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>£398 4s. 3d. 3 per cent.</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>London County Consolidated Stock, 1956/61, at cost</td>
<td>400</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>£321 5s. 6d. 3½ per cent. War Stock, at cost</td>
<td>341</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>£741</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(Value at 31/3/37, £715 11s. 7d.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash at bank, £366 9s. 0d.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXPENDITURE</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Down House—</td>
<td>133</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Contribution towards cost of repairs, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>£133</td>
<td>11</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INCOME</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>By Balance, being excess of Expenditure over Income for the year</td>
<td>133</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>£133</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>No. 8.</td>
<td>Norwich Fund, 1935</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A gift of £105 received from the Local Committee of the Norwich Meeting held there in 1935, to be dealt with at the discretion of the Council.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There have been no receipts or payments during the year, but there are grants outstanding for scientific purposes, but not yet paid, amounting to £100.</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>No. 9.</th>
<th>Radford Mather Lecture Fund</th>
</tr>
</thead>
<tbody>
<tr>
<td>A gift received from Mr. G. Radford Mather in 1936 to establish a Fund, the income therefrom to be devoted to meeting the expense of Triennial Lectures on Recent Advances in Science and their relation to the Welfare of the Community.</td>
<td></td>
</tr>
<tr>
<td>Investment: £248 17s. 6d. 3 per cent. London County Consolidated Stock, 1956/61, at cost £241 8s. 3d. (Value at 31/3/37, £248 17s. 6d.)</td>
<td></td>
</tr>
<tr>
<td>There have been no receipts or payments during the year.</td>
<td></td>
</tr>
</tbody>
</table>
No. 10. Down House

In response to an appeal made in 1927 by Sir Arthur Keith, F.R.S., then President of the British Association, Mr. (now Sir) Buckston Browne, F.R.C.S., acquired the property of Down House, formerly the home of Darwin, and transferred it with an endowment to the Association as a gift to be held as a memorial to Darwin in custody for the nation.

<table>
<thead>
<tr>
<th>Corresponding Figures 31st March, 1930.</th>
<th>Investments:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>£</strong></td>
<td><strong>s.</strong></td>
</tr>
<tr>
<td>5,500</td>
<td>£5,500 India 4½ per cent. Stock, 1958/68, at cost</td>
</tr>
<tr>
<td>2,500</td>
<td>£2,500 Commonwealth of Australia 5 per cent. Stock, 1945/75, at cost</td>
</tr>
<tr>
<td>3,000</td>
<td>£3,000 Fishguard and Rosslare Railway and Harbours 3¼ per cent. Guaranteed Preference Stock, at cost</td>
</tr>
<tr>
<td>2,500</td>
<td>£2,500 New South Wales 5 per cent. Stock, 1945/65, at cost</td>
</tr>
<tr>
<td>2,500</td>
<td>£2,500 Western Australia 5 per cent. Stock, 1945/75, at cost</td>
</tr>
<tr>
<td>3,340</td>
<td>£3,340 Great Western Railway 5 per cent. Consolidated Guaranteed Stock, at cost</td>
</tr>
<tr>
<td>2,500</td>
<td>£2,500 Birkenhead Railway 4 per cent. Consolidated Stock, at cost</td>
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(Value of Stocks at 31/3/36, £25,021 4s. 0d.)

Cash at bank and in hand. £44 2s. 7d.

**EXPENDITURE**

<table>
<thead>
<tr>
<th>Corresponding Figures 31st March, 1930.</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
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<tbody>
<tr>
<td>703 15 10</td>
<td>To Wages of Staff</td>
<td>803</td>
<td>19</td>
</tr>
<tr>
<td>66 5 8</td>
<td>,, Rates, Insurance, etc.</td>
<td>69</td>
<td>5</td>
</tr>
<tr>
<td>86 18 6</td>
<td>,, Coal, Coke, etc.</td>
<td>138</td>
<td>14</td>
</tr>
<tr>
<td>76 3 10</td>
<td>,, Lighting and Drainage (including oil and petrol)</td>
<td>79</td>
<td>4</td>
</tr>
<tr>
<td>16 16 8</td>
<td>,, Water</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>5 5 0</td>
<td>,, Surveyor's Fee</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>—</td>
<td>,, Rain-gauge</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>—</td>
<td>Carried forward</td>
<td>1,107</td>
<td>19</td>
</tr>
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</table>

**INCOME**

<table>
<thead>
<tr>
<th>Corresponding Figures 31st March, 1930.</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
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<tbody>
<tr>
<td>141 0 0</td>
<td>By Rents Receivable</td>
<td>141</td>
<td>0</td>
</tr>
<tr>
<td>168 1 6</td>
<td>,, Income Tax recovered</td>
<td>168</td>
<td>1</td>
</tr>
<tr>
<td>826 8 6</td>
<td>,, Interest and Dividends</td>
<td>817</td>
<td>2</td>
</tr>
<tr>
<td>16 7 2</td>
<td>,, Donations</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>23 8 4</td>
<td>,, Sale of Postcards and Catalogues</td>
<td>23</td>
<td>8</td>
</tr>
<tr>
<td>150 0 0</td>
<td>,, Pilgrim Trust Grant</td>
<td>150</td>
<td>0</td>
</tr>
<tr>
<td>132 3 4</td>
<td>,, Instalment of Grant from Herbert Spencer Bequest</td>
<td>132</td>
<td>3</td>
</tr>
</tbody>
</table>

Carried forward | 1,435 | 12 | 3 |
<table>
<thead>
<tr>
<th>Corresponding Figures</th>
<th>EXPENDITURE</th>
<th>INCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>31st March, 1936.</td>
<td>£  s.  d.</td>
<td>£  s.  d.</td>
</tr>
<tr>
<td>74 13 9</td>
<td>1,107 19 5</td>
<td>Brought forward . . . 1,435 12 3</td>
</tr>
<tr>
<td>To Repairs and Renewals</td>
<td>. . 159 2 4</td>
<td></td>
</tr>
<tr>
<td>&quot; Garden and Land :</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials and Maintenance</td>
<td>. 45 19 8</td>
<td></td>
</tr>
<tr>
<td>5 5 0</td>
<td>. 5 5 0</td>
<td></td>
</tr>
<tr>
<td>&quot; Household Requisites, etc.</td>
<td>. 15 18 10</td>
<td></td>
</tr>
<tr>
<td>2 13 11</td>
<td>. 1 16 6</td>
<td></td>
</tr>
<tr>
<td>&quot; Transport and Carriage</td>
<td>. 8 8 0</td>
<td></td>
</tr>
<tr>
<td>18 18 1</td>
<td>. 35 7 5</td>
<td></td>
</tr>
<tr>
<td>&quot; Accountants’ Fees</td>
<td>. . . . . .</td>
<td></td>
</tr>
<tr>
<td>&quot; Printing, Postage, Telephone, and Stationery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 0 0</td>
<td>. 55 15 1</td>
<td></td>
</tr>
<tr>
<td>&quot; Balance, being excess of income over expenditure for the year transferred to Suspense Account</td>
<td>. . 1,327 9 9</td>
<td></td>
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<tr>
<td>64 2 1</td>
<td>. 1,327 9 9</td>
<td></td>
</tr>
<tr>
<td>1,327 9 9</td>
<td>. 1,327 9 9</td>
<td></td>
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<tr>
<td>1,435 12 3</td>
<td>. 1,435 12 3</td>
<td></td>
</tr>
</tbody>
</table>
RESEARCH COMMITTEES, Etc.

APPOINTED BY THE GENERAL COMMITTEE, MEETING IN NOTTINGHAM, 1937.

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

Seismological investigations.—Dr. F. J. W. Whipple (Chairman), Mr. J. J. Shaw, C.B.E. (Secretary), Miss E. F. Bellamy, Prof. P. G. H. Boswell, O.B.E., F.R.S., Dr. E. C. Bullard, Dr. A. T. J. Dollar, Sir Frank Dyson, K.B.E., F.R.S., Dr. A. E. M. Geddes, O.B.E., Prof. G. R. Goldsbrough, F.R.S., Dr. Wilfred Hall, Mr. J. S. Hughes, Dr. H. Jeffreys, F.R.S., Mr. Cosmo Johns, Dr. A. W. Lee, Prof. E. A. Milne, M.B.E., F.R.S., Prof. H. H. Plaskett, F.R.S., Prof. H. C. Plummer, F.R.S., Prof. J. Proudman, F.R.S., Dr. A. O. Rankine, O.B.E., F.R.S., Rev. C. Rey, S.J., Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, F.R.S., Mr. F. J. Scrase, Capt. H. Shaw, Sir Frank Smith, K.C.B., C.B.E., Sec. R.S., Dr. R. Stoneley, F.R.S., Mr. E. Tillotson, Sir G. T. Walker, C.S.I., F.R.S. £100 (Caird Fund grant).

Calculation of mathematical tables.—Prof. E. H. Neville (Chairman), Dr. J. Wishart (Secretary), Prof. A. Lodge (Vice-Chairman), Dr. W. G. Bickley, Prof. R. A. Fisher, F.R.S., Dr. J. Henderson, Dr. E. L. Ince, Dr. J. O. Irwin, Dr. J. C. P. Miller, Mr. F. Robbins, Mr. D. H. Sadler, Mr. W. L. Stevens, Dr. A. J. Thompson, Dr. J. F. Tocher. £200 (Caird Fund grant).

SECTION A, B, I.—MATHEMATICAL AND PHYSICAL SCIENCES, CHEMISTRY, PHYSIOLOGY.

To co-ordinate the activities of Sections A, B, I, as regards joint symposia, etc., in so far as these relate to the Sciences lying on the border-lines between Physics, Chemistry, and Physiology.—Prof. David Burns, Dr. P. B. Moon, Prof. H. S. Raper, C.B.E., F.R.S., Prof. S. Sugden, F.R.S., Dr. D. M. Wrinch.

SECTION A, C.—MATHEMATICAL AND PHYSICAL SCIENCES, GEOLOGY.

The direct determination of the thermal conductivities of rocks in mines or borings where the temperature gradient has been, or is likely to be, measured.—Dr. Ezer Griffiths, F.R.S. (Chairman), Dr. W. W. Phillip (Secretary), Dr. E. C. Bullard, Dr. H. Jeffreys, F.R.S. (from Section A); Dr. E. M. Anderson, Prof. W. G. Fearsides, F.R.S., Prof. G. Hickling, F.R.S., Prof. A. Holmes, Dr. J. H. J. Poole (from Section C). £40.

SECTION A, J.—MATHEMATICAL AND PHYSICAL SCIENCES, PSYCHOLOGY.

The possibility of quantitative estimates of sensory events.—Prof. A. Ferguson (Chairman), Dr. C. S. Myers, C.B.E., F.R.S. (Vice-Chairman), Mr. R. J. Bartlett (Secretary), Dr. H. Banister, Prof. F. C. Bartlett, F.R.S., Dr. Wm. Brown, Dr. N. R. Campbell, Prof. J. Drever, Mr. J. Guild, Dr. R. A. Houston, Dr. J. O. Irwin, Dr. G. W. C. Kaye, Dr. S. J. F. Philpott, Dr. L. F. Richardson, F.R.S., Dr. J. H. Shaxby, Mr. T. Smith, F.R.S., Dr. R. H. Thouless, Dr. W. S. Tucker, O.B.E.
To excavate critical geological sections in Great Britain.—Prof. W. T. Gordon (Chairman), Prof. W. G. Fearnides, F.R.S. (Secretary), Prof. E. B. Bailey, F.R.S., Mr. H. C. Berdinner, Mr. W. S. Bisat, Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. W. S. Boulton, Prof. A. H. Cox, Miss M. C. Crossfield, Mr. E. E. L. Dixon, Dr. Gertrude Elles, M.B.E., Prof. E. J. Garwood, F.R.S., Mr. F. Gosling, Prof. H. L. Hawkins, Prof. G. Hickling, F.R.S., Dr. R. G. S. Hudson, Prof. V. C. Illing, Prof. O. T. Jones, F.R.S., Dr. Murray Macgregor, Dr. F. J. North, Dr. J. Fringle, Dr. T. F. Sibly, Dr. W. K. Spencer, F.R.S., Prof. A. E. Trueman, Dr. W. S. Wallis, Prof. W. W. Watts, F.R.S., Dr. W. F. Whittard, Dr. S. W. Woolridge. £50 (£25 Bernard Hobson Fund ; £25 contingent, Caird Fund).

To investigate the reptile-bearing oölite of Stow-on-the-Wold, subject to the condition that suitable arrangements be made for the disposal of the material.—Sir A. Smith Woodward, F.R.S. (Chairman), Mr. C. I. Gardiner (Secretary), Prof. S. H. Reynolds, Mr. W. E. Swinton. £25 (Bernard Hobson Fund grant).

To consider and report upon petrographic classification and nomenclature.—Mr. W. Campbell Smith (Chairman and Secretary), Prof. E. B. Bailey, F.R.S., Dr. R. Campbell, Dr. W. Q. Kennedy, Mr. A. G. MacGregor, Dr. S. I. Tomkeieff, Dr. G. W. Tyrrell, Dr. F. Walker, Dr. A. K. Wells. £10.

To investigate the bone-bed in the glacial deposits of Brandon, near Sudbury, Suffolk.—Prof. W. B. R. King, O.B.E. (Chairman), Mr. Guy Maynard (Secretary), Mr. D. F. W. Baden-Powell, Prof. P. G. H. Boswell, O.B.E., Mr. J. Reid Moir, Mr. K. P. Oakley, Mr. C. D. Ovey, Dr. J. D. Solomon, Sir A. Smith Woodward, F.R.S. £5.

To consider and report on questions affecting the teaching of Geology in schools.—Prof. W. W. Watts, F.R.S. (Chairman), Prof. A. E. Trueman (Secretary), Prof. P. G. H. Boswell, O.B.E., F.R.S., Mr. C. P. Chatwin, Prof. A. H. Cox, Miss E. Dix, Miss G. Evans, Prof. W. G. Fearnides, F.R.S., Prof. A. Gilligan, Prof. G. Hickling, F.R.S., Prof. D. E. Innes, Prof. A. G. Ogilvie, O.B.E., Prof. W. S. Pugh, Mr. J. A. Steers, Prof. H. H. Swinnerton, Dr. A. K. Wells.

The collection, preservation, and systematic registration of photographs of geological interest.—Prof. E. J. Garwood, F.R.S. (Chairman), Prof. S. H. Reynolds (Secretary), Mr. H. Ashley, Mr. G. Macdonald Davies, Mr. J. F. Jackson, Mr. A. G. MacGregor, Dr. F. J. North, Dr. A. Raistrick, Mr. J. Ranson, Prof. W. W. Watts, F.R.S.

To consider and report on erosion in part of the coast of Norfolk.—Prof. P. G. H. Boswell, O.B.E., F.R.S. (Chairman), Prof. W. T. Gordon (Secretary), Dr. Burton, Mr. F. Leney, Rt. Hon. E. Lyttelton, Mr. L. M. van Moppes, Mr. J. E. Sainty, Mr. G. Slater, Mr. J. Solomon, Mr. J. A. Steers, Mr. J. S. Wilson, Dr. S. W. Woolridge.

SECTION D.—ZOOLOGY.

To nominate competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Dr. W. T. Calman, C.B., F.R.S. (Chairman and Secretary), Prof. H. Graham Cannon, F.R.S., Prof. H. Munro Fox, Dr. J. S. Huxley, Prof. H. G. Jackson, Prof. C. M. Yonge. £50.

To co-operate with other sections interested, and with the Zoological Society, for the purpose of obtaining support for the Zoological Record.—Sir Sidney Harmer, K.B.E., F.R.S. (Chairman), Dr. W. T. Calman, C.B., F.R.S. (Secretary), Prof. E. S. Goodrich, F.R.S., Prof. D. M. S. Watson, F.R.S. £50.

To investigate the adaptations of freshwater animals to waters of very high salinity in Algeria.—Prof. P. A. Buxton (Chairman), Mr. L. C. Beadle (Secretary), Dr. G. S. Carter, Dr. E. B. Worthington. £50.

To investigate the social behaviour of the grey seal.—Prof. J. Ritchie (Chairman), Dr. Fraser Darling (Secretary), Prof. E. A. E. Crew, Dr. J. S. Huxley, Dr. E. S. Russell. £50.
The progressive adaptation to new conditions in *Artemia salina* (Diplloid and Octoploid, Parthenogenetic v. Bisexual).—Prof. R. A. Fisher, F.R.S. (Chairman), Dr. A. C. Fabergé (Secretary), Dr. F. Gross, Mr. A. G. Lowndes, Dr. K. Mather, Dr. E. S. Russell, O.B.E., Prof. D. M. S. Watson, F.R.S. £20.

To investigate British immigrant insects.—Sir E. B. Poulton, F.R.S. (Chairman), Dr. C. B. Williams (Secretary), Prof. F. Balfour-Browne, Capt. N. D. Riley.

To consider the position of animal biology in the school curriculum and matters relating thereto.—Prof. R. D. Laurie (Chairman and Secretary), Mr. P. Ainslie, Mr. Cousins, Dr. J. S. Huxley, Mr. Percy Lee, Mr. A. G. Lowndes, Prof. E. W. MacBride, F.R.S., Dr. W. K. Spencer, F.R.S., Prof. W. M. Tattersall, Dr. E. N. Miles Thomas.

To confer with the Museums Association on matters concerning the place and function of the Museum in Zoology.—Dr. J. S. Huxley (Chairman), Dr. A. C. Stephen (Secretary), Dr. W. T. Calman, C.B., F.R.S., Prof. W. M. Tattersall, Prof. C. M. Yonge.

**SECTIONS D, I, K.—ZOOLOGY, PHYSIOLOGY, BOTANY.**

To aid competent investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.—Prof. E. W. MacBride (Chairman and Secretary), Prof. Sir J. Barcroft, C.B.E., F.R.S., Dr. Margery Knight, Dr. J. Z. Young. £50.

**SECTIONS D, K.—ZOOLOGY, BOTANY.**

To aid competent investigators selected by the Committee to carry out definite pieces of work at the Freshwater Biological Station, Wray Castle, Windermere.—Prof. F. E. Fritsch, F.R.S. (Chairman), Dr. E. B. Worthington (Secretary), Prof. P. A. Buxton, Miss P. M. Jenkin, Dr. C. H O'Donoghue (from Section D); Dr. W. H. Pearsall (from Section K). £75.

Co-ordinating committee for Cytology and Genetics.—Prof. Dame Helen Gwynne-Vaughan, G.B.E. (Chairman), Dr. D. Catcheside (Secretary), Prof. F. T. Brooks, F.R.S., Prof. F. A. E. Crew, Dr. C. D. Darlington, Prof. R. A. Fisher, F.R.S., Mr. E. B. Ford, Prof. R. R. Gates, F.R.S., Dr. C. Gordon, Dr. J Hammond, Dr. J. S. Huxley, Dr. T. J. Jenkin, Mr. W. J. C. Lawrence, Dr. K. Mather, Dr. F. W. Sansome, Dr. W. B. Turrill, Dr. C. H. Waddington, Dr. D. Wrinch. £5.

**SECTION E.—GEOGRAPHY.**

To inquire into the present state of knowledge of the human geography of Tropical Africa, and to make recommendations for furtherance and development.—Prof. P. M. Roxby (Chairman), Prof. A. G. Ogilvie, O.B.E. (Secretary), Dr. A. Geddes (Assistant Secretary), Mr. S. J. K. Baker, Miss D. M. Doveton, Prof. C. B. Fawcett, Mr. W. Fitzgerald, Prof. H. J. Fleure, F.R.S., Prof. C. Daryll Forde, Mr. R. H. Kinvig, Mr. J. McFarlane, Brig. M. N. MacLeod, D.S.O., Prof. J. L. Myres, O.B.E., F.B.A., Mr. R. A. Pelham, Mr. R. U. Sayce, Rev. E. W. Smith, Brig. H. S. L. Winterbotham, C.B., C.M.G., D.S.O. £2.

To co-operate with bodies concerned with the cartographic representation of population, and in particular with the Ordnance Survey, for the production of population maps.—(Chairman), Prof. C. B. Fawcett (Secretary), The Director General of the Ordnance Survey, Col. Sir Charles Close, K.B.E., C.B., C.M.G., F.R.S., Prof. H. J. Fleure, F.R.S., Mr. A. C. O'Dell, Mr. A. Stevens, Mr. A. V. Williamson.

To consider and report upon ambiguities and innovations in geographical terminology.—(Chairman), Dr. S. W. Wooldridge (Secretary), Mr. H. King, Mr. R. H. Kinvig, Prof. E. G. R. Taylor.
SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Chronology of the world crisis from 1929 onwards.—Prof. J. H. Jones (Chairman), Dr. P. Ford (Secretary), Mr. McDougall (Assistant Secretary), Prof. G. C. Allen, Mr. H. M. Hallsworth, C.B.E., Mr. R. F. Harrod, Prof. J. G. Smith. £25.

SECTION G.—ENGINEERING.

To review the knowledge at present available for the reduction of noise, and the nuisances to the abatement of which this knowledge could best be applied.—Sir Henry Fowler, K.B.E. (Chairman), Wing-Commander T. R. Cave-Browne-Cave, C.B.E. (Secretary), Mr. R. S. Capon, Dr. A. H. Davis, Prof. G. W. O. Howe, Mr. E. S. Shrapnell-Smith, C.B.E. £10 (Contingent, Caird Fund).

Electrical terms and definitions.—Prof. Sir J. B. Henderson (Chairman), Prof. F. G. Baily and Prof. G. W. O. Howe (Secretaries), Prof. W. Cramp, Prof. W. H. Eccles, F.R.S., Prof. C. L. Fortescue, Prof. A. E. Kennelly, Prof. E. W. Marchant, Prof. J. Proudman, F.R.S., Sir Frank Smith, K.C.B., C.B.E., Sec. R.S., Prof. L. R. Wilberforce.

SECTION H.—ANTHROPOLOGY.

To co-operate with a Committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire district.—Mr. M. C. Burkitt (Chairman), Mr. A. Leslie Armstrong (Secretary), Prof. H. J. Fleure, F.R.S., Miss D. A. E. Garrod, Dr. J. Wilfred Jackson, Prof. L. S. Palmer, Mr. H. J. E. Peake. £25.

To conduct anthropometric work in Cyprus.—Prof. J. L. Myres (Chairman), Mr. L. Dudley Buxton (Secretary), Dr. G. M. Morant, Miss M. L. Tildesley. £25.

To conduct archaeological excavations in the Fens.—Prof. J. H. Hutton, C.I.E. (Chairman), Mr. K. H. Jackson (Secretary), Mr. M. C. Burkitt, Dr. J. D. G. Clark, Miss Eleanor Hardy, Mr. T. C. Lethbridge. £25 (Leicester and Leicestershire Fund).

To investigate early mining sites in Wales.—Mr. H. J. E. Peake (Chairman), Mr. Oliver Davies (Secretary), Prof. V. Gordon Childe, Dr. C. H. Desch, F.R.S., Mr. E. Estyn Evans, Prof. H. J. Fleure, F.R.S., Prof. C. Darryl Forde, Sir Cyril Fox, Dr. Willoughby Gardner, Dr. F. J. North, Mr. V. E. Nash Williams. £8.

To investigate blood groups among primitive peoples.—Prof. H. J. Fleure (Chairman), Prof. R. Ruggles Gates, F.R.S. (Secretary), Dr. F. W. Lamb, Dr. G. M. Morant. £7.

To co-operate with a committee of the Royal Anthropological Institute in assisting Miss G. Caton-Thompson to investigate the prehistoric archaeology of the Kharga Oasis.—Prof. J. L. Myres, O.B.E. (Chairman), Miss G. Caton-Thompson (Secretary), Dr. H. S. Harrison, Mr. H. J. E. Peake.

To report on the probable sources of the supply of copper used by the Sumerians.—Mr. H. J. E. Peake (Chairman), Dr. C. H. Desch, F.R.S. (Secretary), Mr. H. Balfour, F.R.S., Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. Davies, Prof. H. J. Fleure, F.R.S., Dr. A. Raistrick, Dr. R. H. Rastall.

To co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern.—Sir A. Keith, F.R.S. (Chairman), Prof. J. L. Myres, O.B.E., F.B.A. (Secretary), Mr. M. C. Burkitt, Miss D. A. E. Garrod, Mr. A. D. Lacaille.

To carry out research among the Ainu of Japan.—Prof. C. G. Seligman, F.R.S. (Chairman), Mrs. C. G. Seligman (Secretary), Dr. H. S. Harrison, Capt. T. A. Joyce, O.B.E., Rt. Hon. Lord Raglan.
To report on the classification and distribution of rude stone monuments in the British Isles.—Mr. H. J. E. Peake (Chairman), Dr. Margaret A. Murray (Secretary), Mr. A. L. Armstrong, Mr. H. Balfour, F.R.S., Mrs. E. M. Clifford, Sir Cyril Fox, Mr. T. D. Kendrick.

To conduct archæological and ethnological researches in Crete.—Prof. J. L. Myres, O.B.E., F.B.A. (Chairman), Dr. G. M. Morant (Secretary), Mr. L. Dudley Buxton, Dr. W. L. H. Duckworth.

To report to the Sectional Committee on the question of re-editing ‘Notes and Queries in Anthropology.’—Prof. H. J. Fleure, F.R.S. (Chairman), Mr. Elwyn Davies (Secretary), Dr. H. S. Harrison, Dr. G. M. Morant, Prof. C. G. Seligman, F.R.S., Mrs. C. G. Seligman.

SECTION I.—PHYSIOLOGY.
To deal with the use of a stereotactic instrument.—Prof. J. Mellanby, F.R.S. (Chairman), Prof. R. J. S. McDowall (Secretary).

SECTION J.—PSYCHOLOGY.
To develop tests of the routine manual factor in mechanical ability.—Dr. C. S. Myers, C.B.E., F.R.S. (Chairman), Dr. G. H. Miles (Secretary), Mr. H. Binns, Prof. C. Burt, Dr. F. M. Earle, Dr. Ll. Wynn Jones, Prof. T. H. Pear. £50.

The nature of perseveration and its testing.—Prof. F. Aveling (Chairman), Dr. W. Stephenson (Secretary), Prof. F. C. Bartlett, F.R.S., Dr. Mary Collins, Prof. J. Drever, Mr. E. Farmer, Prof. C. Spearman, Dr. P. E. Vernon. £10 (Contingent grant, Caird Fund).

SECTION K.—BOTANY.
Transplant experiments.—Sir Arthur Hill, K.C.M.G., F.R.S. (Chairman), Dr. W. B. Turrill (Secretary), Prof. F. W. Oliver, F.R.S., Prof. E. J. Salisbury, F.R.S., Prof. A. G. Tansley, F.R.S. £5 (Leicester and Leicestershire Fund).

SECTION L.—EDUCATIONAL SCIENCE.
To consider and report on the possibilities of organising and developing research in education.—Prof. F. Clarke (Chairman), Miss D. Bailey, Mr. A. Gray Jones, Dr. M. M. Lewis, Mr. W. H. Robinson, Mr. J. Sargent. £5 (Leicester and Leicestershire Fund).

To consider and report on the gaps in the informative content of education, with special reference to the curriculums of schools.—Sir Richard Gregory, Bart., F.R.S. (Chairman), Mr. G. D. Dunkerley (Vice-Chairman), Mr. A. E Henshall (Secretary), Prof. C. M. Attlee, Miss L. Higson, Mr. H. G. Wells. £10 (Leicester and Leicestershire Fund).

CORRESPONDING SOCIETIES.
Corresponding Societies Committee.—The President of the Association (Chairman ex-officio), Dr. C. Tierney (Secretary), the General Secretaries, the General Treasurer, Dr. Vaughan Cornish, Mr. T. S. Dymond, Prof. W. T. Gordon, Dr. A. B. Rendle, F.R.S., Prof. J. Ritchie, Dr. G. F. Herbert Smith.
RESOLUTIONS & RECOMMENDATIONS.

The following resolutions and recommendations were referred to the Council by the General Committee at the Nottingham Meeting for consideration and, if desirable, for action:

From Section A (Mathematical and Physical Sciences).

That Section A, on the occasion of a visit to the grave of George Green, the world-famous mathematician of Nottingham, viewed with some concern the deterioration that is taking place in the tombstone, and would respectfully suggest that representations be made to the proper authorities to take such steps as seem fit to maintain in good condition the resting-place of this renowned man.

From Section D (Zoology).

That the Committee of Section D, having learned from the public press that the buildings and collections of the Museum established at Tring by the late Lord Rothschild have been bequeathed to the nation on condition that the Trustees of the British Museum undertake their custody and maintenance, desire to record their opinion that the continuance of the Tring Museum as an active centre of scientific research is a matter of the utmost importance from a national, and indeed from an international, point of view. For many years the collections preserved there, more particularly the vast and unequalled collection of Lepidoptera, have attracted research workers from all over the world and have been the means of adding largely to our understanding of the problems of geographical variation. The Sectional Committee earnestly desire that the permanent conservation of these collections and the continuance of the facilities for their study provided by the munificence of the late Lord Rothschild will be ensured by their being placed in the custody of the Trustees of the British Museum.

The Committee request the Council of the British Association to bring this expression of opinion to the notice of the Trustees of the British Museum.

From Section E (Geography).

That the Sectional Committee of Section E learn with great regret of the discontinuance by the Ordnance Survey of the fifth (relief) edition of the one-inch map. This map marked an advance in the cartography of the country in that it gave, for the first time, invaluable data for the study of land forms. Much geographical work has been done in those areas for which sheets have been published, and the Committee view with grave concern the prospect of having to abandon work in other areas, or to postpone it indefinitely, in consequence of the suspension of this edition.

Further, the Committee feel that the issue of special relief printings without names and other detail, which was initiated with this edition, provided for the first time an adequate base map for studies in land forms and regional geography; and it would urge that, whether the fifth (relief) edition be proceeded with or not, sheets showing relief and water features only in the style of the fifth (relief) edition should be available.
From Section G (Engineering).

That following the Presidential Address delivered to Section G by Sir Alexander Gibb, the Sectional Committee considered what action could best be taken by the British Association to assist in improving and co-ordinating the various forms and channels in which new engineering knowledge is now published. Improvement is urgently required and the Institution of Civil Engineers is already taking action to this end. The Engineering Section of the British Association, however, is in touch with such an exceptionally wide range of engineering that it sees the importance and also the difficulty of co-ordinating all branches of engineering in the matter of publications.

It is therefore recommended that letters be written on behalf of the Council to the Institution of Civil Engineers and to the Department of Scientific and Industrial Research, drawing attention to the great importance of improving the co-ordination of arrangements for publishing and indexing new engineering knowledge and the results of engineering research, and expressing a hope that any new system which is being developed may be made to cover the widest possible range.

From Section H (Anthropology).

That in view of the importance of anthropology as a means of promoting concord and understanding between men of different traditions, the British Association earnestly recommends to H.M. Government that anthropology should be made a compulsory subject of study in the training of all probationers appointed to proceed to India or Burma.

From Section L (Educational Science).

That in view of the great contribution that an extended system of adult education might make to the political and cultural life of the nation, it be urged that H.M. Government be asked to refer the question of developing adult education either to the Consultative Committee of the Board of Education or to any other appropriate Committee.

From the Conference of Delegates of Corresponding Societies, supported by Section D (Zoology).

That the Council of the British Association be requested to represent to His Majesty’s Minister of Agriculture and to His Majesty’s Secretary of State for Scotland, the necessity of instituting an inquiry to ascertain the effects, in respect of efficiency, economic reactions, and humaneness, of available methods of dealing with rodents and other wild mammals that affect agriculture.

From the Conference of Delegates of Corresponding Societies.

That the Conference recommend to the Council of the British Association the desirability of establishing through its Corresponding Societies’ Committee a close liaison with the Association for the Study of Systematics in Relation to General Biology with a view to the Corresponding Societies undertaking work bearing upon systematic problems.
Sir William Thomson, in his Address at Edinburgh in 1871, said that 'the real origin of the British Association' was given in the words of a letter written by David Brewster to John Phillips on February 23, 1831, a few months before the first meeting: 'The principal object of the Society would be to make the cultivators of science acquainted with each other, to stimulate one another to new exertions, and to bring the objects of science more before the public eye, and to take measures for advancing its interests and accelerating its progress.' That the time was fully ripe for the birth of the Association is made very clear by the words written by John Keble to a friend, referring to the D.C.L. degrees conferred, at the Oxford meeting in 1832, on David Brewster, Robert Brown, John Dalton and Michael Faraday: 'The Oxford Doctors have truckled sadly to the spirit of the times in receiving the hodge-podge of philosophers as they did'—an opinion on which Lord Salisbury commented at the Oxford meeting in 1894: 'It is amusing at this distance of time, to note the names of the hodge-podge of philosophers whose academical distinctions so sorely vexed Mr. Keble's gentle spirit.' It is not only amusing but pathetic that such words should have been used by a revered member of a University which had done
splendid service for science, as has been so well shown in Dr. R. T. Gunther's volumes.¹

Faced by the serious duty of preparing this address, I felt that the best hope of interesting you would be to choose a subject which has received special attention at our meetings. I have selected the progress of thought on Organic Evolution as it may be followed in addresses, papers, and discussions, mainly restricting myself to the series of meetings which began with the Jubilee at York in 1881, the first of many that I have had the pleasure of attending.

The British Association provides a very favourable field for the discussion of many-sided subjects such as Evolution—subjects which attract members from very different as well as from closely related Sections. Hence a wide range of varied experience is open to one who can look back over more than half a century; and I do not propose to exclude some of the humorous sayings and incidents which, from time to time, have enlivened our meetings and contributed to their success. Some of them certainly deserve to be rescued from oblivion, although to perform this pious duty I must risk the enmity of the Goddess of Folly, who as Erasmus tells us, proclaimed: 'I hate a man who remembers what he hears.'

The Fiftieth Anniversary at York was a memorable meeting, with Sir John Lubbock (Lord Avebury) as President, and the Chair of every Section except Economics, under Grant Duff, taken by a Past-President of the Association.

I then enjoyed to the full one of the chief benefits conferred by our Association upon its younger members—the opportunity of meeting older men, up to that time only known to them by the fame of their discoveries. Prof. O. C. Marsh had come over from Yale, his main object being to buy for his University Museum the second and more perfect fossil of the wonderful ancestral bird Archaeopteryx, with teeth and a long, lizard-like tail—clear evidence of Reptilian origin. The earlier example had been bought for the British Museum at a price which was said to have provided the dowry for a professor's daughter, and Marsh soon realised, as he told me, that the second was not for sale on any terms. 'We let the other go and I believe they would kill me if this were sold' was the reply given to him by the authority in Munich. He was able, however, to study the fossil, and his description and drawings of the teeth, in the Geological Section, followed the only attack on Evolution itself, as distinct from its causes, which I have ever witnessed at any of our meetings. It was the exhibition by H. G. Seeley of his reconstruction of Archaeopteryx from this fossil,

¹ Early Science in Oxford, vols. i–xi.
which aroused the fury of the palæontologist, old Dr. Thomas Wright of Cheltenham: ‘Archæopteryx hasn't got a head, how can it possibly have teeth?’ he growled, knowing nothing of the latest find or of the fact that Sir John Evans, our President at Toronto, had discovered a detached head and scattered teeth on the slab in which the older specimen was embedded. In spite of Prof. Newton’s positive statement and the form of the teeth, drawn by Prof. Marsh at the request of the Chairman, Dr. Wright, quite unconvinced, continued muttering ‘Archæopteryx is a very good bird,’ its virtue in his opinion entirely uncontaminated by any taint of Reptilian affinity.

Prof. Marsh also read a paper in the Zoological Section on his own wonderful discoveries of toothed birds from the rocks of the western United States. Richard Owen, President of the Section, was in the Chair and, with the memory of old and embittered controversies in his mind, the author told me that he had felt rather anxious in bringing this communication forward. But in that friendly atmosphere there was no reason for alarm. Owen welcomed the paper warmly and in confirmation told us, in the most charming manner, of the traces of teeth found in an embryo parrot.

The event which stands out most clearly in my memories of the Jubilee meeting is Huxley's evening lecture on ‘The Rise and Progress of Palæontology’—the science which provides an essential part of the foundation on which Geographical, Geological and Biological evolutionary history has been built. The insuperable difficulty felt by the older naturalists was to believe that the land had been for the most part deposited under the sea, and to account for the presence of fossils, or as they were called, 'formed stones.' The true solution, Huxley explained, was found and published in 1669 by Nicholas Steno, a Danish Professor of Anatomy at Florence, who carefully studied certain fossils, known as 'glossopetrae,' which abounded in the Tuscan rocks and were believed to be fossil fig-leaves. Steno, who was not satisfied with this interpretation, dissected a shark's head and showed that the 'glossopetrae' exactly corresponded in every particular with the teeth—'that in fact they were shark's teeth.' The emphasis with which Huxley made this statement comes back to me after the lapse of nearly sixty years. From this Steno was led to conclude that they were the teeth of shark-like fishes living in the Tuscan sea and later embedded, with other remains, in the strata which had there accumulated.

I have not noticed the fanciful suggestion of 'fossil fig-leaves' in any published version or account of Huxley's lecture that I have seen, but he certainly told us of it and it is an interesting example of the attempts made by the naturalists of the day to explain the fossils embedded in rocks then believed to be of terrestrial origin. I
cannot resist the temptation of quoting Plot's more ingenious and amusing effort to account for the well-known layer of oyster-shells (Ostrea bellovacina) found at some places here in England, particularly at Cats-grove [now Katesgrove] near Reading; which how they should come here without a Deluge, seems a difficulty to most men not easily avoided.'

Plot was, however, helped 'to a salvo' for his own objection by remembering that Reading was a Town of very great action during the Invasions of the Danes, who cutting a deep trench cross between the Kennet and Thames, and inclosing themselves as it were in an Island, held it against King Ethelred, and Alfred his Brother a considerable time; from whence in all probability, the Saxons having removed their Cattle and other provisions before the Danes arrival, 'tis likely they they might be supplied from their Navy with Oysters, which during the time of the aboad of the Army on Land, might be a very suitable employment for it: Which conjecture, if allowed, there is nothing more required to make out the possibility of the bed of Oysters coming thither without a Deluge, but that Cats-grove was the place appointed for the Armies repast.'

The probability of this suggestion may be inferred from the age of the Woolwich and Reading beds in which the oysters are found—estimated by my friends Prof. Watts and Prof. Hawkins at about 50 to 60 million years.

Dr. Plot's explanation of fossils in general as well as of flowers was of a very different kind. To account for their existence he appealed to 'the wisdom and goodness of the Supreme Nature, by the School-men called Naturans, that governs and directs the Natura naturata here below, to beautifie the World with these varieties; which I take to be the end of such productions as well as of most Flowers, such as Tulips, Anemones, &c. of which we know as little use as of formed stones.'

The modest and withal amusing paragraph which follows I venture to quote in full as an example to be followed in scientific controversy:

'And thus I have given the grounds of my present opinion, which has not been taken up out of humor or contradiction, with intent only to affront other worthy Authors modest conjectures, but rather friendly to excite them, or any others, to endeavor collections of shell-fish, and parts of other Animals, that may answer such formed stones as are here already, or may hereafter be produced: Which when ever I find done, and the reasons alleged solidly answered, I

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2 The Natural History of Oxfordshire, being an Essay toward the Natural History of England, by Robert Plot, D.D. Printed at the Theater in Oxford. 1677. Dedicated To the most Sacred Majesty of Charles the Second, King of Great Britain, France and Ireland, Defender of the Faith, etc. (pp. 118–122).
shall be ready with acknowledgment to retract my opinion, which I am not so in love with, but for the sake of Truth I can cheerfully cast off without the least reluctance.'

One chief object which, as I believe, Huxley had before him was to bring forward a calm, clear statement of the evidence on which alone it was possible to achieve that 'reconstruction of an extinct animal from a tooth or bone,' which had made so deep an impression on the imagination. The reconstruction was in fact a simple inference based on anatomical experience such as that gained by Steno when he dissected the shark and concluded that the 'glossopetrae' were the teeth of shark-like fishes. But this reasoning—that a fossil tooth or bone on the surface of a rock, cannot by itself enable the geologist to predict that a skeleton of a certain type lies hidden beneath—seeming to diminish the glory of Cuvier's splendid work, was resented by Owen who had replied with the bitter taunt that a tooth can tell us a great deal—a donkey can kick his master but he cannot eat him. This may have been the encounter referred to by Huxley when he wrote of a friendly meeting with Owen at the Zoological Section of the Association in Leeds (1858): 'so that the people who had come in hopes of a row were (as I intended they should be) disappointed.'

In the same spirit, I think, Huxley was glad to speak of the 'glossopetrae' at the Jubilee meeting, where Owen was President of a Section, and calmly and simply, to reaffirm conclusions which are unassailable.

Huxley then passed on to Steno's further study of fossils and his proof of their relationship to terrestrial freshwater and marine organisms, and to his application of this evidence to the past condition of Tuscany—all discussed 'in a manner worthy of a modern geologist' and later extended by Buffon to all parts of the world then known to be fossiliferous. These conclusions, 'which almost constitute the framework of palæontology,' only required one addition, made towards the end of the eighteenth century by William Smith, who showed that geological strata contained characteristic fossils so that rocks of the same age could be identified in all parts of the world, while the biologist could follow the changes in the living population of the globe—a record of constant extinction and continual generation of new species. We were then led to three general conclusions: (1) the vast length of time during which life has existed on the earth—'certainly for millions of years'; (2) the continual changes which living forms have undergone during this period; (3) the successive changes in the best-known fossil groups are such as we should expect if each series 'had been produced by the gradual modification of the earliest form. . . .' This last conclusion meant evolution which so completely accorded with

recent discoveries that 'if it had not existed, the palæontologist would have had to invent it.'

I can never forget the words spoken to me after the lecture by a dear friend of my youth, the late Viriamu Jones, Principal of University College, Cardiff: 'At every sentence I felt myself bowing to Huxley and saying "you are the greatest man here; no one else could have said that as you have said it."

As Huxley's lecture continued in a calm spirit an embittered controversy, so his thoughts on the immensity of past geological and biological time lead naturally to another controversy on the age of the earth conducted intermittently at our meetings between 1892 and 1921. It is, I think, a good example of the invaluable help which the British Association brings to discussion when there appears to be a difficulty in reconciling the conclusions reached by the followers of different sciences. Lord Kelvin's estimate of a hundred million years as the period during which the earth had been cool enough to permit the existence of life upon its surface—a period reduced by Prof. Tait to ten million—was a great difficulty to geologists and biologists who believed that an immensely longer time was required for the history of the fossiliferous rocks and the evolution of animals and plants. Thus, to quote only one instance, Darwin writing to Wallace in 1871 and referring to 'missing links,' said, 'I should rely much on pre-Silurian time; but then comes Sir William Thomson, like an odious spectre.' The geologists resisted more firmly. Thus Sir Archibald Geikie, in his Presidential Address at Edinburgh in 1892, concluded his discussion of the subject with these words: 'The geological record furnishes a mass of evidence which no arguments drawn from other departments of Nature can explain away, and which, it seems to me, cannot be satisfactorily interpreted save with an allowance of time much beyond the narrow limits which recent physical speculation would concede.' At the Leeds meeting in 1890 I had many opportunities of meeting Prof. John Perry, and when we were walking together on the Sunday afternoon I asked him to tell me something of the Kelvin-Tait conclusions and how far they must be accepted. He had been a demonstrator under Kelvin and spoke of the intense interest with which he had followed his lectures at Glasgow, and he gave me no hope of escape. His change of opinion, throwing a most interesting light upon the influence of the British Association, was the result of the Presidential address at Oxford in 1894, when Lord Salisbury chaffed the believers in natural selection, telling them that he did not wonder that they required many hundred million years for so slow a process, but that if the mathematicians are right, the biologists cannot have what they demand. . . . The jelly-fish would have
been dissipated in steam long before he had had a chance of displaying the advantageous variation which was to make him the ancestor of the human race.' When Perry read this pronouncement, sweeping aside the firm convictions of biologists and geologists, he was led to re-examine the evidence and soon found a flaw. The heat of the earth had been calculated on the assumption of a conductivity uniform through the whole mass, but Perry showed that with a conductivity becoming higher with increasing depth the Kelvin-Tait estimate of the time required for cooling to the existing temperature—on which the age of the habitable earth had been based—must be immensely lengthened. Perry told me of this destructive criticism and very kindly helped me to make use of it in the address to Section D at Liverpool in which I replied to Lord Salisbury's amusing attack on the evolutionists.

Lord Lister was our President at Liverpool in 1896, and I cannot resist the temptation to digress for a moment and recall the address in which one of the greatest benefactors of mankind told us, with the utmost simplicity and modesty, the story of his life's work and the success which, in spite of all opposition, had been achieved. To hear him was an enduring inspiration.

The year 1896 was also the Jubilee of Lord Kelvin's wonderful half-century of achievement in research and teaching, and I could not help feeling some regret that any criticism of his work should appear at this particular time. But in the kindly spirit of our Association such doubts were quite unnecessary. I well remember how he came one day to our Sectional Committee-room to bring me some volumes of his works, and how, as I have recorded before, in the following year as we were travelling across Canada after the Toronto Meeting and the chance of collecting insects for a few minutes at each station could not be resisted, Lord Kelvin said to his wife, 'My dear, I think we must forgive Poulton for thinking that the earth is so very old when he works so hard in one day out of all the endless millions of years in which he believes I.'

The one line of evidence which left some anxiety in 1896, was suggested by Helmholtz who allowed the sun only eighteen million years to have been giving out radiant heat at the present rate—a period Lord Kelvin was willing to extend to 500 million—and this estimated maximum was also accepted by Sir George Darwin, who, in his address at Cape Town in 1905, spoke of the new evidence obtained by M. and Mme. Curie in their proof that radium gives out heat, and, quoting in confirmation the work of R. J. Strutt, W. E. Wilson, and G. H. Darwin, finally concluded that 'the physical argument is not susceptible of a greater degree of certainty

4 Report, British Association, Centenary Meeting, 1931, p. 78.
than that of the geologists, and the scale of geological time remains in great measure unknown.' The light thrown by radium upon the Helmholtz estimate was also referred to in the Presidential Address of Ray Lankester at York in 1906, of J. J. Thomson, quoting the work of Strutt, Joly and Rutherford, at Winnipeg in 1909, and became a predominant subject in the Joint Discussion on the Age of the Earth, between Sections A, C, D and K, at Edinburgh in 1921. Lord Rayleigh in opening this discussion concluded 'that radioactive methods of estimation indicate a moderate multiple of 1,000 million years as the possible and probable duration of the earth's crust as suitable for the habitation of living beings. . . .' 

Even in the present year Sir Ambrose Fleming, in his address to the Victoria Institute, is reported in The Times of January 12 to have maintained that 'We were not in possession of any generally agreed scientific modes of geological time measurement, but only with estimates which were based for the most part on personal predilection or guesses at truth.' It is to be regretted that the conclusions of scientific colleagues should be attributed to 'personal predilection,' and as for 'guesses at truth'—what are these but hypotheses; and surely the discoverer whose imaginative effort led to the thermionic valve and did so much to endow the world with the infinite possibilities of wireless—surely he has little cause to choose for the serious efforts of others the word which in this connection carries a suggestion of shallow irresponsibility.

Geologists and biologists do not profess to know the age of the earth as the abode of life, but they are sure that, in the words used by Sir William Turner at Bradford in 1900, its birth 'must have been in the far-distant past, at a period so remote from the present that the mind fails to grasp the duration of the interval.'

I fear that too much of our time has been occupied by the attempt to show that the field is clear for the discussion of Organic Evolution, but, until this could be done, any such discussion appeared to be well-nigh useless.

It is, I think, a mistake to emphasise too strongly the very natural shock received by many who read the Origin or heard of its teaching for the first time and without any preparation; and I believe an even greater mistake to criticise the clergy for the time that elapsed before their acceptance of the new teaching. I shall never forget the reception of Aubrey Moore's paper, 'Recent Advances in Natural Science in their Relation to the Christian Faith,' by the Church Congress at Reading in 1883. No speaker could have carried his audience with him more thoroughly: there was not a single protest or indication of dissent—nothing but enthusiastic

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6 Report, British Association, 1921, pp. 413-415.
applause. The Bishop of Oxford, Dr. Mackarness, was in the chair when the paper received this unanimous welcome—only twenty-three years after the Oxford meeting at which another Bishop of Oxford put his rude and foolish question to Huxley. It is pleasant to know that their celebrated encounter left no bitterness, for Huxley wrote in 1891 to Francis Darwin—'In justice to the Bishop, I am bound to say that he bore no malice, but was always courtesy itself when we occasionally met in after years.'

I remember as a youth receiving a gentle parental warning against committing myself too entirely to a belief in evolution—a very different experience from that of our President at Hull in 1922, my friend Sir Charles Sherrington, who in 1873 was persuaded by his mother to take the Origin with him on his summer holiday, with the inspiring words—'It sets the door of the Universe ajar!'

I have already recalled Dr. Wright's indignation at York in 1881 as my only experience of opposition to a belief in Organic Evolution at any of our meetings, and the published Proceedings confirm this impression of unanimity. Thus, R. H. Traquair, addressing the biologists at Bradford in 1900, said, 'I hardly think that we should now find a single scientific worker who continues to hold on to the old special creation idea'; and Lord Salisbury at Oxford in 1894, referring to Darwin, said, 'He has, as a matter of fact, disposed of the doctrine of the immutability of species. It has been, mainly associated in recent days with the honoured name of Agassiz, but with him has disappeared the last defender of it who could claim the attention of the world.' The mention of this great American naturalist recalls Tyndall's fine address at Belfast in 1874 and his memories of Agassiz's words, 'I was not prepared to see this theory received as it has been by the best intellects of our time. Its success is greater than I could have thought possible.'

Huxley, who had seconded the vote of thanks to Lord Salisbury, wrote to Hooker a few days later: 'It was very queer to sit there and hear the doctrines you and I were damned for advocating thirty-four years ago at Oxford, enunciated as matters of course—disputed by no reasonable man!—in the Sheldonian Theatre by the Chancellor. . . .' 8

A letter written two days earlier to Boyd Dawkins records Huxley's opinion of another part of the address. 'Lord Salisbury gave himself away wonderfully, but he was so good about Darwin himself that I shut my eyes to all the nonsense he talked about Natural Selection.' 9

9 From a letter of August 10, 1894, printed in the Jesus College (Oxford) Magazine, for Lent Term, 1928; and reprinted in Hope Reports, vol. xvi, 1929, No. 3, p. 6. (Privately circulated to many scientific libraries.) Huxley's letter of August 18, 1894, to Lewis Campbell (Life and Letters, vol. ii, p. 379) refers to the same subject.
Leaving now the subject of Organic Evolution itself, as generally accepted, I wish to speak on the difficult question of its motive causes which for many years have formed the subject of addresses, discussions and papers at our meetings. The great division into two opposed theories of causation became clear in 1887 when Weismann attended the meeting at Manchester, and a discussion on 'The Hereditary Transmission of Acquired Characters' was held in Section D. From that time evolutionists attending our meetings have been either 'Lamarckians,' following Erasmus Darwin, Lamarck, Buffon and Herbert Spencer, or 'Darwinians' who followed Darwin and Wallace. Darwin himself, however, included the Lamarckian conception of 'use-inheritance' as a motive cause, although believing it to be far less important than Natural Selection. The term 'Neo-Darwinian' has therefore been applied to those who, accepting Weismann's teaching, reject 'use-inheritance' altogether.

It must always be remembered that, apart from any theory of causes, the world owes its belief in organic evolution to all the great men whose researches and teaching have founded the two schools, and perhaps chiefly, at any rate among the English-speaking nations, to Herbert Spencer. I was first led to realise the extent of his transatlantic popularity when I learned from an American story greatly enjoyed in those far-off undergraduate days, that his books were keenly appreciated by a bashful hero, who was so far from sharing the sublime confidence of their author, that he was only led to perform the most fateful action in life by the pressing advice of a very young nephew who assured him, in the presence of the lady, that if he was fond of her, the proper thing to do was to kiss her. Herbert Spencer's infallibility certainly lent itself to such stories as that of his supposed reply to an argument—'That can't be true, for otherwise First Principles would have to be re-written—and the edition is stereotyped'; or how Darwin said that to read Spencer always made him feel like a worm, but that he retained the worm's privilege of wriggling, and at another time 'wonderfully clever, and I dare say mostly true.' But, allowing for a style which provoked these and other amusing comments, we must never forget that believers in the doctrine of Organic Evolution owe an immeasurable debt to Herbert Spencer.

James Russell Lowell's amusing lines in the Biglow Papers appear to prove that Lamarckism was prevalent in America many years before the Origin:

'Some flossifers think thet a fakkilty's granted
The minnit its proved to be thoroughly wanted,'
Ez, fer instance, thet rubber-trees fust begun bearin’
Wen p’litikkle conshunces come into wearin’,—
Thet the fears of a monkey, whose holt chanced to fail,
Drawed the vertibry out to a prehensile tail.’

The year of the Manchester meeting, 1887, was the fiftieth anniversary, and we are now celebrating the Centenary, of the entry in Darwin’s pocket-book:

‘In July opened first note-book on Transmutation of Species. Had been greatly struck from about the month of previous March on character of South American fossils, and species on Galapagos Archipelago. These facts (especially latter), origin of all my views.’

It is especially interesting to recall that these views, as Professor Newton told us in his address to D, the Biological Section, did not include Natural Selection which only came into Darwin’s mind when he read Malthus, On Population, in October, 1838. Newton, who had read the proof-sheets of the great Life of Darwin, published later in 1887, then spoke of Wallace’s independent discovery, made twenty years after Darwin’s, a discovery suggested to him also by reflecting on Malthus, and of the friendship between the two great men to whom this fruitful conception had come, referring the cynic who would ‘point the finger of scorn at the petty quarrels in which naturalists unfortunately at times engage’ to this ‘greatest of all cases, where scientific rivalry not only did not interfere with, but even strengthened, the good-feeling which existed between two of the most original investigators.’ And here I cannot resist the desire to quote a part of the speech made by Wallace at the most thrilling scientific gathering I have ever attended—the fiftieth anniversary of the Darwin-Wallace Essay read before the Linnean Society on July 1, 1858, only twelve days after the arrival of Wallace’s letter and manuscript from the Moluccas. Wallace then said, on July 1, 1908:

‘The idea came to me, as it had come to Darwin, in a sudden flash of insight: it was thought out in a few hours . . . and sent off to Darwin—all within one week. I was then (as often since) the “young man in a hurry”: he, the painstaking and patient student, seeking ever the full demonstration of the truth that he had discovered, rather than to achieve immediate personal fame. . . . If the persuasion of his friends had prevailed with him, and he had published his theory, after ten years’—fifteen years’—or even eighteen years’ elaboration of it—I should have had no part in it whatever, and he would have been at once recognised, and should be ever recognised, as the sole and undisputed discoverer and patient investigator of the great law of “Natural Selection,” in all its far-reaching consequences.’

11 Darwin-Wallace Celebration of the Linnean Society of London, 1908, pp. 6, 7.
Amusing evidence of the difficulty with which this 'great law' was understood is afforded by a verse written by Lord Neaves and dated May, 1861:

'A deer with a neck that was longer by half
Than the rest of its family's (try not to laugh),
By stretching and stretching, became a Giraffe,
Which nobody can deny.'  

Yet Wallace, referring to Lamarck's hypothesis and 'that now advanced,' had written in his Section of the Joint Essay:

'Neither did the giraffe acquire its long neck by desiring to reach the foliage of the more lofty shrubs, and constantly stretching its neck for the purpose, but because any varieties which occurred among its antitypes with a longer neck than usual at once secured a fresh range of pasture over the same ground as their shorter-necked companions, and on the first scarcity of food were thereby enabled to outlive them.'

There were fortunately others who did not launch such ill-aimed criticism. Thus Professor Newton, reminding the Section that the new teachings had been at once accepted by Canon Tristram before the appearance of the Origin of Species (on November 24, 1859), expressed, with all the enthusiasm of one who was devoted to the same delightful branch of natural history, 'the hope that the study of ornithology may be said to have been lifted above its fellows.' It was indeed very fortunate that the Darwin-Wallace Essay should have been read so soon after its appearance by a naturalist who looked on the species question as did Tristram—a great traveller and observer who studied indefatigably the birds he loved, as living creatures and in as many countries as he could visit.

At the last meeting of the British Association in Nottingham (1893) Canon Tristram was President of Section D and, in his address, gave an account of the observations referred to by Newton at Manchester. The historic interest of this early acceptance of Natural Selection is such that I have prepared a brief abstract of his chief conclusions:

During a visit of many months to the Algerian Sahara in 1857-58, he 'noticed the remarkable variations in different groups, according to elevation from the sea, and the difference of soil and vegetation.' On his return he read the Darwin-Wallace Essay and wrote, 'It is hardly possible, I should think, to illustrate this theory better than by the larks and chats of North Africa.' He then explained how the colours arose by selective destruction of birds which harmonised less well than others with the surface of the desert. And similarly with other larks having 'differences, not only of colour, but of

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18 Ibis, October, 1859, pp. 429-433.
structure,' chiefly 'marked in the form of the bill.' He took as
instances a very long-billed lark (Galerita arenicola), resorting
exclusively to the deep, loose, sandy tracts, and a very short-billed
allied species (G. isabellina), haunting the hard and rocky districts.
He then pointed out that there is individual variation in the bills
of larks and that the shorter-billed birds would be at a disadvantage
in obtaining food from sandy areas but at an advantage among the
rocks where strength is required. He concluded, 'Here are only
two causes enumerated which might serve to create, as it were, a new
species from an old one. Yet they are perfectly natural causes,
and such as I think must have occurred, and are possibly occurring
still. We know so very little of the causes which, in the majority of
cases, make species rare or common that there may be hundreds of
others at work, some even more powerful than these, which go to
perpetuate and eliminate certain forms "according to natural means
of selection."

The temptation to record an amusing incident which happened
at one of the meetings of Section D at Manchester, cannot be
resisted. Work was proceeding smoothly under the genial guidance
of Prof. Newton when, suddenly, Dr. Samuel Haughton of Dublin
entered and from the back of the room announced in arresting tones
that he had an important communication to make about the animals
preserved from the Flood. He believed that Mrs. Noah strongly
objected to her husband's intention to take the elephants on board,
fearing that their weight would cause a dangerous displacement of
the Ark's metacentre. How this domestic difference was composed
we had no opportunity of learning, for as the Chairman, whose
expression combined sympathetic amusement with mild deprecation,
was rising and about to protest, Dr. Haughton, anticipating the
result, had already turned towards the door, telling us over his
shoulder that he was on his way to make a fuller communication
on the subject to the Anthropological Section.

After this brief description of an event, which I hope you will agree
ought not to be forgotten, we must return to Organic Evolution and
to one of the most important subjects debated at any time before a
meeting of the British Association—the question, 'Are Acquired
Characters Hereditary? '—brought before the world by Prof. August
Weismann, who was present at Manchester and spoke in the discus-
sion (unfortunately not reported), introduced by Ray Lankester,
in which Dr. Hubrecht, Patrick Geddes, Marcus Hartog and the
present speaker, took part. Weismann's conclusion that 'Acquired
Characters' are not inherited, was held by Prof. Goodrich, in his
address to Section D at Edinburgh in 1921, to be 'the most important
contribution to the science of evolution since the publication of Darwin's *Origin of Species,* an opinion with which the great majority of biologists will agree, although the terms employed for the two classes, the Inherited and the Non-inherited, together with the ideas underlying them, were shown by Adam Sedgwick, at Dover in 1899, Archdall Reid, and others, as well as by Goodrich himself, to be incorrect. Nevertheless it will probably be impossible to abandon the word 'acquired,' employed by Erasmus Darwin (1794), Lamarck (1809), and Prichard (1813) as well as by later authorities. Whenever environmental conditions are followed by characteristic changes, absent when these conditions are absent; or when such changes follow the use or disuse of the parts of an organism, or the education it has received, then we have before us the 'acquired' characters maintained by Weismann to be incapable of hereditary transmission. This vital conclusion, accepted, as I believe it is, by nearly all biologists, is not appreciated as it ought to be by the general public. A brief statement of a single piece of evidence may convince some who are doubtful about a conclusion with which human life is very deeply concerned.

My old friend the late A. A. Macdonell, Professor of Sanskrit at Oxford, spoke two languages, English and German, as they are spoken by native Englishmen and Germans. I asked him whether he thought it was possible for any mature person to learn a foreign language so perfectly that he would be mistaken for a native. He replied that he was sure it could not be done and that his own ability to speak the two languages as he did had been only made possible because as a small child he had been continually taken backwards and forwards between the two countries. Yet any human being transported as a baby from his own country to another and brought up there among the natives will learn to speak as they speak. All the past generations, however many, during which his ancestors spoke the language at his birthplace, will count for nothing, will not retard his acquisition of another tongue or modify it in any way.

An interesting and amusing example is provided by the futile striving of an Englishman to pronounce the Welsh double-*l,* generally attempted by the substitution of 'th.' And even the advice given by a Welsh clergyman to the English Bishop of his diocese is unlikely to bring success: 'You must put the tip of your Right Reverend tongue against the roof of your Right Reverend mouth, and hiss like a goose.'

The result of education as an 'acquired' character in the Weismannian sense is of such special importance that I think it is well to quote the conclusions stated by Sir Ray Lankester in his address to the seventy-fifth meeting of the Association at York. He then maintained that the 'power of building up appropriate cerebral mechanism
in response to individual experience, or what may be called "educability," is the quality which characterises the larger cerebrum, and is that which has led to its selection, survival, and further increase in volume. "Educability" can be transmitted; it is a congenital character. But the results of education can not be transmitted. In each generation they have to be acquired afresh. On the other hand, the nerve-mechanisms of instinct are transmitted, and owe their inferiority as compared with the results of education to the very fact that they are not acquired by the individual in relation to his particular needs, but have arisen by selection of congenital variation in a long series of preceding generations.  

Lankester was led by these conclusions to reject altogether the theory of G. H. Lewes, G. Romanes, and others, that instincts are due to lapsed intelligence, a theory also disproved by Lloyd Morgan's observations on young birds described by him at the Ipswich meeting in 1895. Another very important subject brought forward by Lankester was the evidence, originally published by him in 1894, that Lamarck's first and second laws of heredity are contradictory the one of the other, and therefore may be dismissed. His statement may be briefly summarised as follows:

The first law assumes that in spite of thousands of generations during which a normal environment has moulded the individuals of a given species of organism, and determined as each individual developed and grew "responsive" quantities in its parts (characters); yet, as Lamarck tells us, and as we know, there is in every individual born a potentiality which has not been extinguished. Change the normal conditions ... and (as Lamarck bids us observe), in spite of all the long-continued response to the earlier normal specific conditions, the innate congenital potentiality shows itself. The individual ... shows new responsive quantities in those parts of its structure concerned, new or acquired characters.

So far, so good. What Lamarck next asks us to accept, as his "second law," seems not only to lack the support of experimental proof, but to be inconsistent with what had just preceded it. The new character which is ex hypothesi, as was the old character ... which it has replaced—a response to environment ... is, according to Lamarck, all of a sudden raised to extraordinary powers. The new or freshly acquired character is declared ... to be capable of transmission by generation; that is to say, it alters the potential character of the species. It is no longer a merely responsive

14 Report, British Association, 1906, pp. 26–27. The conclusions here quoted had been communicated to Société de Biologie of Paris, in 1899 (Jubilee Volume) and were reprinted in Nature, vol. lxi, 1900, pp. 624–625.

15 Report, British Association, p. 734.

or reactive character, determined quantitatively by quantitative conditions of the environment, but becomes fixed and incorporated in the potential of the race, so as to persist when other quantitative external conditions are substituted for those which originally determined it.'

The effect of Lamarck's laws on the hereditary transmission of acquired characters would be this: 'A past of indefinite duration is powerless to control the present, while the brief history of the present can readily control the future.'

After hearing a very condensed statement of conclusions so essentially bound up with the progress of Organic Evolution, I feel sure that you will wish to be reminded of Prof. Ewing's words which followed the address at York:

'Now is the winter of our discontent made glorious summer by this Ray of Lankester.'

Returning to the unreported discussion on the inheritance of acquired characters at Manchester, I venture to bring forward certain observations opposed to a belief in Lamarckian evolution by means of inherited experience—observations which I then described and have not known to be answered. In the relationship between enemy and prey there is very commonly no opportunity for the latter to learn by experience. The wonderfully elaborate adaptations by which sedentary insects are hidden from enemies have been evolved, not by experience of enemies but by avoidance of enemies. In these examples, and they are numberless, we are driven to accept Weismann's conclusion and with him to invoke 'the all-sufficiency of Natural Selection.' When one of the twig-like caterpillars, of which there are so many in this country, is detected by an insectivorous bird it can do nothing and is devoured at once. Its one defence is the astonishingly perfect resemblance to a twig of the bush or tree on which it lives. It is firmly fixed and its weight also supported by an almost invisible thread so that it cannot escape as many caterpillars do by dropping to the ground and sheltering in the grass or among dead leaves. Its one chance of survival is to gain so perfect a disguise that it will not be seen, and to attain this end the adaptive devices are most elaborate and wonderful: its twig-like shape and colours with the power of gradually adjusting these so as to resemble the bark of the bush or tree on which the parent moth laid the egg from which it came, even the power to reproduce exactly the appearance of lichen, the rigid stick-like attitude maintained during the hours of daylight. Finally there is the evidence, recently obtained by Robert Carrick,\(^{17}\) that the disguise does protect; for examples of one of these caterpillars, resting on

a branch of its food-plant fixed over a wren’s nest containing young, were unnoticed by the parent bird which used the same branch as a convenient perch; yet seen and at once taken when placed on a white surface below.

One of the best examples of a prophetic instinct is to be found in the larva of an African Tabanid fly (T. biguttatus). This maggot lives and feeds in soft mud which, during the dry season when the chrysalis stage has been reached, will be traversed in all directions by wide and deep cracks in which insectivorous animals can search for prey. But the maggot, while the mud is still soft, prepares for this danger. By tunnelling spirally up and down it makes a line of weakness which will cause a pillar to separate from the mass when the mud hardens and contracts. It then tunnels into the still soft pillar and becomes a chrysalis in the centre of its deeper end. However wide the cracks which appear in the mud, the maggot has arranged beforehand that they will not invade its cylinder. Dr. W. A. Lamborn, who made this most interesting discovery, observed that the summits of the pillars, forming circular discs of about the size of a penny, scattered here and there over the surface, were never thus traversed, but that an empty shell was protruding from the centre of each when the fly had emerged.18 My friend the late Prof. J. M. Baldwin, the distinguished American psychologist, well remembered at many of our meetings, wrote when he heard of this discovery: ‘it seems complete—one of those rare cases of a single experience being sufficient to establish both a fact and a reason for the fact! It is beautiful.’

I would ask any believer in Lamarckian evolution, or in Hering’s and Samuel Butler’s theory of unconscious memory residing in the germ-cells, how it would be possible to explain these prophetic instincts, adapted not to meet but to avoid future experience, except by the operation of natural selection.

The appeal to Orthogenesis, or internal developmental force, as the motive cause of evolutionary progress has often been made—generally by palaeontologists rather than by the observers of living forms. Any such belief in the potency of an internal tendency is, I think, open to the criticism made by Thiselton Dyer in his address to Section D at Bath in 1888: ‘This appears to me much as if we explained the movement of a train from London to Bath by attributing to it a tendency to locomotion. Mr. Darwin lifted the whole matter out of the field of mere transcendental speculation by the theory of natural selection, a perfectly intelligible mechanism by which the result might be brought about. Science will always

prefer a material *modus operandi* to anything so vague as the action of a tendency."

It is not necessary for me to speak on the rediscovery of Mendel’s great work and all that it has meant to our Biological Sections in the early decades of the present century. The recent developments, following the work of Haldane, R. A. Fisher, and others, and the vitally important relationship between Mendelism and Natural Selection were brought before us last year in Julian Huxley’s illuminating address to Section D. The older belief that only large variations, or mutations as they then began to be called, were subject to Mendelian inheritance, and that small variations were not inherited at all, disappeared when further researches proved that extremely minute differences were ‘heritable in the normal Mendelian manner,’ and, with this, the foundation of Darwinian evolution became immensely strengthened. It is also right to remember that Bateson, the leader of Mendelian research in this country, always believed in Natural Selection, regarding it indeed as self-evident and not very interesting. Also that Ray Lankester, as long ago as his 1906 address at York, maintained that however far Mendelism was advanced it ‘would not be subversive of Mr. Darwin’s generalisations, but probably tend to the more ready application of them to the explanation of many difficult cases of the structure and distribution of organisms.’

The relationship between the germinal foundation of Mendelian and Weismannian heredity was considered in a paper by L. Doncaster read before Section D at the South African meeting in 1905. He then maintained that Weismann’s ‘hypothesis that the material bearer of hereditary qualities is the chromatin of the nucleus’ of the germ-cells had been confirmed by recent work on their matura-
tion which ‘has shown that they contain a mechanism which seems precisely adapted to bring about that segregation of characters which forms the most fundamental part of the Mendelian theory, and it seems hardly possible that the two things are unconnected.’ MacBride also, in his address to the same section at Newcastle in 1916, spoke of the ‘great epoch-making discovery of experimental embryology, viz. the existence of specific organ-forming substances.’ These fundamental discoveries bring to mind a conversa-
tion with Weismann when he had been finally driven to frame and elaborate this hypothesis, and was so appalled by the number and minuteness of the material bearers of hereditary qualities contained in a single germ-cell that, as he told me, he could not believe that the physicists and chemists were correct in their conclusions about the size of the atom. He admitted that diverse lines of evidence led to

19 *Report, British Association, 1931, p. 77* and references quoted.
the same result, but even so, he believed the future would prove that physicists were mistaken and that the atom was far smaller.

It is impossible to say more than a few words about the very interesting and important discussion on 'The present state of the Theory of Natural Selection' held at the Royal Society on May 14 last year. The subject was approached from many points of view by both zoologists and botanists, and their conclusions were very welcome to Darwinians who remembered the earlier opinions expressed when Mendel's great work was rediscovered. I think, however, that Prof. D. M. S. Watson, in the opening address, was inclined to underestimate the value of the existing evidence for a 'selective death rate,' although everyone will agree that 'any new evidence . . . or indeed any suggestion of cases which might be capable of investigation,' would be most desirable.

I may briefly mention a few experiments brought before Section D at the Bristol meeting in 1898 beginning with the work of Weldon and Thompson on the Common Shore Crab, showing that the effect of china clay and other impurities in the sea at Plymouth was selective and promoted changes of shape which ensured that the water flowing over the respiratory surface was more efficiently filtered.

Then, on the subject of chance, the heroic help rendered by Mrs. Weldon, who four times recorded the result of 4,096 throws of dice, showing that the faces with more than three points were on the average, uppermost slightly more often than was to be expected. It comes back to me very clearly because of the interesting explanation—that the points on dice are marked by little holes scooped out of the faces, and that points 6, 5, and 4, respectively opposite 1; 2, and 3 are somewhat lighter, more of the ivory having been removed; also because of Francis Galton's delight and his humorously expressed wonder whether the facts had been realised by those who had an interest other than scientific in the throwing of dice.

Experimental evidence was also submitted by Miss Cora B. Sanders (Mrs. C. B. S. Hodson) and myself, proving that when the rough, angular pupa of the small tortoiseshell butterfly 'is suspended from a surface against which it stands out conspicuously, it is in far greater danger than when it is fixed to one upon which it is concealed.'

To the observer of living creatures, however, the most convincing evidence is provided by animals themselves. When a wild bird is seen to capture some conspicuous butterfly or moth and then immediately to reject it the association between inedibility and a warning colour is more convincingly suggested than when insects are offered to animals in confinement, although such experiments
are of great value and often provide the only available evidence. There are, however, instances in which abundant data for statistical investigation are furnished by the wild animals themselves. Thus the long-eared bat has the convenient habit of eating moths—its regular food—while it hangs suspended from a surface to which it returns after each capture; and as the wings are rejected, these may be collected in large numbers, yielding valuable information on the significance of concealing and warning patterns.

In the attempt to determine the motive causes of organic evolution, the work of the naturalist, the student of living nature, is essential. His task is to do what Lyell did for geology by directing attention to the forces now in operation and seeking with their help to interpret the past. By the death of Lord Rothschild, on August 28, the world has lost a great naturalist who devoted his life to the creation of a splendid museum offering unique opportunities for the study of modifications which arose as the species of an important Insect Order (Lepidoptera) gradually spread over the areas which they now occupy. It was his wish that this immense field for research upon these latest phases of evolutionary change should become the property of the Nation, forming a magnificent addition to the British Museum. I feel confident that it is the earnest hope of us all that Lord Rothschild's wish may be realised and that this great memorial of a life devoted to Natural History will provide constant inspiration to many workers in the same branch of science.

Associated with these researches is the study of adaptations which have been developed in recent times and can, in certain instances, be proved to undergo changes even now. Thus the interesting observations of H. Lyster Jameson showed that a pale local race of the common mouse had been formed, although incompletely, in from 100 to 125 years, by the selective attacks of owls and hawks on sandhills near Dublin.\(^{20}\) I have long believed that the colours of animals provide one of the most fruitful fields in which to pursue these investigations, and I regret that this work has been recently attacked by an American zoologist who, referring to the recent revival of natural selection, continues—"if the doctrine can emerge minus its sexual selection, its warning colors, its mimicry and its signal colors, the reaction over the end of the century will have been a distinct advantage."\(^{21}\) It is of course impossible to discuss, on the present occasion, this confident attempt to depreciate the value of work associated with the names of Darwin, Bates, Wallace, Trimen and Fritz Müller. I will only point out

\(^{21}\) *Evolution.* A. Franklin Shull. (New York, 1936.)
that the conclusions on warning colours and mimicry have been immensely strengthened and confirmed by the later observations of Guy Marshall, W. A. Lamborn, St. Aubyn Rogers, Hale Carpenter, V. G. L. van Someren, C. F. M. Swynnerton and others in Africa; by the experiments conducted by some of these naturalists, and also by H. B. Cott and R. Carrick, and in the United States by Morton Jones.

It is interesting to remember that a paper by two American entomologists 22 was among the first to accept and support by fresh observations the conclusions brought forward by H. W. Bates in his great memoir on the mimetic butterflies of the Amazon Valley, 23 and that one of the authors treated the same subject more completely in a later paper 24 much appreciated by Darwin. 25

It is also important to remember that the above-mentioned conclusions have been reached by the study of marine animals no less than terrestrial, as was shown by Herdman in his address to Section D at Glasgow in 1901, and by his experiments communicated to the same Section at Ipswich in 1895; also that Garstang, with his very long and intimate experience of marine life, adopts the same interpretation of colour and form with the associated attitudes and movements.

If time permitted it would be possible to speak of numerous papers on mimicry and the related subjects which have been brought before our meetings. It is impossible to attempt this now, but many will feel with me that the name of the late Dr. F. A. Dixey should not be forgotten—one who attended so regularly, so often read papers at our meetings, presided over Section D at Bournemouth in 1919, lectured at Leicester in 1907, always giving the results yielded by the study of his favourite insects, and their interpretation by the theory of natural selection; also one who delighted in the social gatherings of his Section, where his rendering of Widdicombe Fair will be long remembered.

In my concluding remarks I am anxious to refer to a very interesting and encouraging subject—the feeling for animals and the care for their welfare to-day, as contrasted with the treatment they received a hundred years ago and even in the youth of many among us. Only last autumn The Times of October 12, reported that 1,000 swallows had arrived at Venice 'sent there by bird-lovers from Vienna and Munich in order to save them from the effects of

24 Riley: Third Annual Report on the Noxious ... Insects of ... Missouri, 1871, p. 142.
the cold weather. Soon after their arrival they were set free and flew south along the Adriatic coast.' And a little earlier the writer of the amusing 'Fourth Leader' referred to a meeting of the Society for the Preservation of the Fauna of the Empire at which the care of the opossum was discussed, comparing this with the report of happenings a hundred years earlier when there was a 'humorous debate' at the Zoological Society 'about puffing cigar-smoke into the cages of the monkeys,' to their evident discomfort. The writer, yielding too far, we hope, to the depression of the present day, concludes: 'The world, it may be, is "man-sick" and yearning to be rid of a bad mistake. But the creature cannot be wholly vile when instead of torturing monkeys it takes thought for the opossum.' It would not be right to quote from a century-old report without speaking of all that is done and has been done during many years for the care and health of animals by the great London Society and its branch at Whipsnade, and in doing this, for the education and happiness of our people. But the change of which I have spoken is most deeply impressed on those who remember, as many of us do, the misdirected hours in youth when birds were shot in our gardens and brick traps made to catch them. I feel sure that those who did these things are not essentially different from their children and grandchildren who have grown up in a kinder atmosphere. I must not occupy more time on a subject which to some may seem inappropriate, but it is bound up with education in its true sense—the detection and training of unrecognised ability—and if, as Sir Ray Lankester said at York, and we are all coming to believe, the hidden powers within are inherited while the results of their development are not, then there is no easing of the burden with the passage of time, but each generation afresh must bear the heavy responsibility of conducting this development in the best way so that its successor may be able to meet the changing and, at this time, the increasing needs. The relationship between the powers within and their development was suggested in arresting words by the late Prof. Scott Holland: 'To say that a man cannot be made good by Act of Parliament is such an obvious truth that people forget what an outrageous lie it is!'

Thoughts on the development of these hidden powers by the educating influence of social environment, suggest the greatest of the problems by which we are faced—the end of international war. Sir Michael Foster, in his Address at Dover in 1899, after speaking of progress in the material of warfare was led to believe that, 'happily, the very greatness of the modern power of destruction is already becoming a bar to its use, and bids fair—may we hope before long?—wholly to put an end to it; in the words of Tacitus, though in another
sense, the very preparations for war, through the character which science gives them, make for peace.' And in his concluding pages he expressed the hope that the brotherly meeting between the English and French Associations at Dover and Boulogne might be looked upon as a sign that science, by nobler means than the development of armaments, was steadily working towards the same great end. And, in a time of still greater need and perplexity, may we not, in the same hopeful spirit, look upon the recent visit by which members of the French Association have honoured us, and feel strengthened in the belief that the great end will be reached.

There are, I know, very many people who look upon the Great War with later wars and rumours of wars as the close of Sir Michael Foster’s dream. The words in which Sir Arthur Schuster concluded his address at Manchester in 1915, and Sir Edward Thorpe at Edinburgh in 1921, indicate, I hope, that the British Association does not thus despair, and in this belief I bring before you a passage from the far earlier address which Sir Richard Owen delivered to the Twenty-eighth Meeting at Leeds in 1858—a passage which makes a special appeal at a time when the British and American Associations are confidently hoping to strengthen still further the bonds of sympathy and mutual appreciation by which they have been happily united for so many years.

Referring to the transatlantic telegraph Sir Richard said:

‘We may confidently hope that this and other applications of pure science will tend to abolish wars over the whole earth; so that men may come to look back upon the trial of battle between misunderstanding nations, as a sign of a past state of comparative barbarism; just as we look back from our present phase of civilisation in England upon the old border warfare.’

Confident words inspired by the forging of a new link between the two great English-speaking nations. Nearly eighty years have passed since they were spoken, but with all the terrible disappointments there has been great progress, and a time will surely come, and may it come quickly, a time which shall prove that the visions of the young and the dreams of the old were prophetic of a glorious reality.
SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

NOISE AND THE NATION

ADDRESS BY
G. W. C. KAYE, O.B.E., M.A., D.Sc.,
PRESIDENT OF THE SECTION.

Applied Physics and related Matters
Acoustics and the British Association
Noise and the Nation.
The Measurement of Noise.
The Decibel and the Phon.
Noise Meters.
   (i) Subjective Noise Meters.
   (ii) Objective Noise Meters.
The Analysis of Noise.
Noise Level Measurements.
Noise on the Railway.
Noise in the Air.
Noise on the Road.
   (i) Ministry of Transport Tests.
   (ii) Tests on New Motor Vehicles.
   (iii) Tests on 'Used' Motor Vehicles.
   (iv) Summary of Tests.
   (v) Motor Horns.
   (vi) Pneumatic Road Drills.
The Abatement of Noise.
Quiet Housing.
   (i) The Insulation of Walls and Windows.
   (ii) The Insulation of Floors.
   (iii) Sound Absorbent Treatment of Rooms.

APPLIED PHYSICS AND RELATED MATTERS.

There is a feeling, which of late years has been gathering strength, that
the primary concern of the British Association should be to bring home
to the community how much its welfare and its interests owe, and are
likely to owe in the future, to science and its developments. Our
President at Blackpool last year emphasised this outlook in his address
on 'The Impact of Science on Society'; and we in Section A have
thought it well this Coronation year to devote the greater part of our
proceedings to some of the beneficent influences of applied physics on
the complex social and industrial life of the nation. We feel that in
these disturbed days science should have a message of goodwill to the world; and to such a message, fortified at each of our sessions by practical demonstration, we have put our hand at this sectional gathering, now meeting for the third time in the great industrial city of Nottingham.

A generation ago it was fashionable to draw a working distinction between the applied and pure physicist, it being considered that when given a piece of research to carry out, the former consciously or unconsciously applied Benjamin Franklin's stock question 'What is the use of it?' Nowadays it is appreciated that any such distinction can only be largely artificial, for there have been many outstanding illustrations during the last half century of how speedily and inevitably results of no preconceived practical value may glide into widespread industrial utilities. For example, when only forty years ago Sir J. J. Thomson discovered the electron, no one could ever have imagined that, as Dr. K. T. Compton recently informed us, an industrial business amounting to some hundreds of millions of pounds a year would now owe its existence to electronic devices. Already, both neutrons and radio-sodium are being experimented with in radiation therapy; and furthermore, some of the artificial radioactive elements have found an important field of use in biological processes, both in animals and plants, providing, as they do, by their characteristic radioactive decay, a method of identifying migrating atoms a million times more sensitive than any that analytical chemistry can offer. Again, to judge by the 1936 report of the Comptroller-General of the Patent Office, technical applications are also being sought for the transmutation of elements by bombardment with short-wave radiation or high-speed particles.

Thus even the most practically minded among us need find no difficulty in appreciating the profound fascination and basic significance of some of the present-day developments of modern physics, and recognising the driving genius behind them. But applied physics has its victories no less than pure physics; and speaking as one who has spent some thirty happy years in both the pure and applied schools of physical research, I can testify that dealing with materials which are neither intangible nor ephemeral, does not necessarily cramp outlook or stifle enthusiasm; and applied workers are no less able to share the stimulus of conquering a stubborn investigation, and with it all, enjoy the satisfaction of seeing many of their labours turned to early account in the interests of the community. Perhaps some day they will also take to heart some of the social implications of their work.

There must be many of us, both workers and onlookers, who at times feel a little overwhelmed by the way the ramifications of physical research year by year continue to extend. Not uncommonly, the methods of attack are so involved and the technique so formidable, that despite the great all-round improvements in equipment, the calls on the pertinacity and patience of the worker are no less than in the past. Incidentally, while present-day equipment is often much more elaborate and efficient, it is also apt to be much more costly than that of a generation ago, as those who direct physical laboratories are well aware. This applies alike to the pure and the applied physics laboratory; and although their
immediate objectives are usually very different, one finds, for example, in both the Cavendish and National Physical Laboratories, ample illustration of how large-scale and expensive apparatus has entered into both classes of physical investigation. Such apparatus is likely to be beyond the compass of the private research worker, who at one time cut a conspicuous figure in the scientific annals of this country, but who, with a few noteworthy exceptions, has now regrettably disappeared. Progress in industrial research, at any rate, seems to be more and more bound up with specialised team attack, whether to solve a specific problem or to develop a new invention or product.

There is one other matter to which I would like to refer. It has been claimed in some quarters that man's qualities of leadership are more likely to be developed by the older humanitarian studies than by the natural or mechanical sciences. The dictum has doubtless the defects of all such generalisations, and more to the point, perhaps, is the summing up of John Drinkwater, that 'the minds of men mostly belong to one or other of two kinds—the kind that wishes to dominate, and the kind that desires to understand.' Experience tempts one to hazard the view that the proportion of men who naturally seek leadership or administrative responsibility is small, possibly one in twenty or even less. Provided, however, the germs of initiative and common sense are there, the value of research in getting a man into the way of thinking for himself and developing a courageous and discriminating outlook is not to be questioned. It is to be hoped that the penetration into the major industries of scientifically trained young men, whose mental equipment is such as to fit them later on for responsible administrative jobs, is something which the Universities regard as of high national importance. In its turn, industry must play a part by recognising the advantages of admitting the pick of such men into the Board room more commonly than in the traditional past. Power without knowledge is a well-worn and discredited experiment in this country; and the conception that technical or scientific workers invariably require to be mothered by full-blooded non-scientific or quasi-scientific administrators is manifestly so much moonshine.

Before leaving the subject, I may perhaps comment on what I believe to be a weakness of a good many thoroughly capable men who come to an appointment fresh from a University and armed with an Honours science degree and perhaps a little research experience; that is, a difficulty in setting down their ideas and conclusions on paper concisely and logically and in reasonably good English, whether in letter or report. We must not, of course, expect to find old heads on young shoulders, but I feel sure that some sort of intensive course to cover these points ought to form a part of young people's University training; or perhaps we ought to insist on a more thorough grounding, particularly in English, before specialisation in science is allowed to begin. As it is, the drafting of a scientific paper by a beginner is liable to be an ordeal which is, I think, best tempered by the system of joint publication with a senior man, the experience being not only valuable educationally but often an eye-opener for both parties.
Acoustics and the British Association.

In passing to the subject matter of this Address, I may perhaps mention that a search through the Reports of the Association reveals that throughout its entire existence of over a hundred years, no previous Presidential Address in Section A has dealt with acoustical matters. Neither can I find a precedent for an experimental address such as I am venturing to offer you to-day. It is fitting that the subject of acoustics should occupy us in this lecture theatre, which was one of Prof. Barton's last achievements.

During the course of the search, one could not fail to be impressed by the galaxy of distinguished mathematicians and physicists who have presided over our Section in the past. Here is a random selection of pre-war names: Brewster, Herschel, Forbes, Stokes, Airy, Rankine, Cayley, Wheatstone, Tyndall, Maxwell, Tait, Balfour Stewart, Lord Kelvin, Carey Foster, Johnstone Stoney, the late Lord Rayleigh, Chrystal, G. H. Darwin, Fitzgerald, Sir Oliver Lodge, Schuster, Glazebrook, Rucker, Hicks, Sir J. J. Thomson, Prof. Forsyth, Poynting, Larmor, Sir Chas. Boys, Lamb, Sir Napier Shaw, Lord Rutherford, Hobson, Turner, Callendar, Baker, Sir Frank Dyson and Prof. Whitehead.

Except for two war years (1917 and 1918), the British Association has never failed to meet annually, nor has the Section omitted to play its part. Since the war, we find further names no less eminent: Andrew Gray, Prof. O. W. Richardson, Prof. G. H. Hardy, McLennan, Sir Wm. Bragg, Sir George Simpson, Prof. Porter, Prof. Whittaker, Prof. A. Fowler, Lord Rayleigh, Sir Frank Smith, Sir J. J. Thomson, Prof. Rankine, Sir Gilbert Walker, Macdonald, Dr. Aston and Prof. Ferguson.

It was not until 1843 (twelve years after the inaugural year of the British Association) that the first Presidential Address was given to the Section of Mathematics and Physics by M'Cullagh. His lead was by no means always followed in subsequent years, and even when it was, the address had clearly assumed no particular moment. Stokes's Sectional address in 1862 seems to have occupied about four minutes, while Whewell, the renowned Master of Trinity, in the course of a brief address four years earlier at Leeds, lamented the small size of the meeting room, but on reflection thought it might suffice, as 'we in this Section are very much in the habit of treating our subjects in so sublime a manner that we thin the room very speedily.' Since about 1868, the Sectional programme has invariably included a Presidential Address, though over a long period it was given no title. Lord Kelvin, ever a stalwart supporter of the British Association, was the first to supply a title (in 1876) and kept up the practice in his later addresses, his example being followed by Sir Robert Ball in 1887. But the innovation found no other supporters, and it was not until 1911 that Prof. Turner adopted a title; since 1920 the Presidential Addresses in Section A have all borne titles.

As regards the two previous Nottingham meetings, at the first of these in 1866, Wheatstone apparently dispensed with a Sectional Address; while at the second meeting in 1893, the late Sir Richard Glazebrook gave an address on optical theories and the ether. Those who then
contributed papers included Fitzgerald, the late Lord Rayleigh, Oliver Lodge, Lord Kelvin, Barton, Larmor, Carey Foster, Viriamu Jones, and J. J. Thomson.

During the first fifty years of the Association, it was not uncommon for the Sectional Presidency to be held on more than one occasion by the same man, viz. Whewell and Lord Kelvin were each elected President on five occasions while Brewster, Herschel, the Earl of Rosse, Forbes, Stokes and the then Dean of Ely each held the office twice. Since 1884 it has become the practice for the Sectional Chair to be occupied by a newcomer. To this, there has been only one, though a very notable exception, namely Sir J. J. Thomson, who presided in 1896 and again at the memorable Centenary meeting in London in 1931.

That acoustics was long the Cinderella of the physical sciences is apparent from the sustained Presidential cold-shoulder, though even in the very earliest meetings the subject was not without its supporters. At the second meeting, at Oxford in 1832, Wheatstone read two papers on acoustics, one of them experimental. The Rev. Mr. Wills also gave 'An Account of the Recent Additions to our Knowledge of the Phænomena of Sound,' though it is recorded that the printing of the paper was deferred; which seems to have been a polite way of shelving it!

At the 1834 meeting, there was a paper by Addams on 'A New Phænomenon of Sonorous Interference' which was accompanied by an experimental demonstration. In the following year at Dublin, there were no fewer than four acoustical papers, including one by Wheatstone 'On the various Attempts which have been made to imitate Human Speech by Mechanical Means,' while in a remarkably penetrating paper 'On the Construction of Public Buildings in reference to the Communication of Sound,' Dr. Reid of Edinburgh recognised reverberation as the most prevalent acoustic defect of large rooms and explained how it could be reduced by excluding superfluous space by hanging draperies, or by making the walls more absorbent through greater roughness or irregularity. He also condemned concave surfaces as promoting uneven distribution of sound. Thus the prime and vital factors of good architectural acoustics were clearly recognised as long as a century ago, but did not reach the ear of the architectural profession, so that countless halls with poor acoustics have since been, and still are being erected. The British Association of to-day aims at a more effective publicity in all such matters of general concern.

Tyndall, during his Sectional Presidency in 1868, gave evidence before a Select Committee on the acoustics of the House of Commons, stressing the value of a low ceiling as a reinforcing device, and the beneficial influence of an audience (as in the Cambridge Senate House) or of draperies in quenching the after-sound in a room. Again, Johnstone Stoney, who was Sectional President in 1879, described in 1885 a method of treating walls to free concert halls or public rooms from echo effects.

It was the late Lord Rayleigh, our Sectional President in 1882, to whom with Helmholtz we owe the enduring foundations of a great deal of modern acoustics. Kelvin never said a truer thing when he remarked that progress in a science hinges on measurement; this indeed is the
keynote of the new motto of the British Association 'Sed omnia disposuisti' (But Thou hast ordered all things in measure and number and weight.) Rayleigh was almost alone in his day in improvising with rare simplicity and skill measuring devices in acoustics. But in many ways his voice was one crying in the wilderness, for until the telephone came into general use, acoustics had been of little service to the people, and there was small interest in the subject at either schools or Universities. Many of us will recall the shabby treatment meted out to sound in the physics curricula of those days.

The touchstone came with the thermionic valve, which led to electrical methods of measurement and so to higher precision, as elsewhere in physics. The gramophone, wireless, broadcasting and the talking pictures followed each other in succession; and now acoustics, far from being a Cinderella, has become a radiant Princess of physics in whose career the public interest has become completely enchained. Her 'open sesame' revealed the interior of the Abbey last May to countless millions, who were vouchsafed a vivid acoustic imagery of the Coronation ceremony. For such technical miracles, no praise can be too high for the skilled army of technical and industrial workers who see to it that developments in invention, equipment and technique follow each other like a river in spate. The literature is immense, and I can only surmise that the commercial value of applied acoustics must run into many millions of pounds. At any rate, I can testify, as its Chairman, that a Committee of the British Standards Institution was occupied for nearly two years in the careful scrutiny and compilation of a glossary of the large and steadily expanding acoustical terminology. So much acoustical research is now being carried out, that an authoritative glossary, particularly in the matter of units, is manifestly of the first importance in the comparison of experimental results from different laboratories and the application of such data to engineering acoustics. Sound has become a marketable commodity the cultural and political developments of which, particularly in regard to broadcasting, are not easy to envisage.

**Noise and the Nation.**

Simultaneously with these developments in applied acoustics, there has gradually developed in this country a public consciousness of the insidious growth of the social evil of needless noise—a pernicious by-product attributable in great part to an increasingly mechanised civilisation. With this growing realisation, the nation is beginning to demand and to receive protection against the nuisance of outrageous noise whether generated by private or public bodies. It is looking for ways and means of mitigating excessive transport noises particularly on the road and in the air, and it is seeking to know why in modern houses or flats it should not be accorded adequate privacy against the natural though sometimes unreasonable noises of neighbours.

All this is not to say that John Citizen cherishes the ideal of a completely silent world, for due noise in due season unquestionably contributes to the spice of life. It should indeed be emphasised that in this matter he
is not crying for the moon. The most he needs ask of a particular locality is that its background of noise, whether by day or night, shall be suited to the environment and the reasonable habits of a majority of its occupants.

In this matter of noise abatement, the British Association has played a leading part, through the intermediary of both this Section and the Engineering Section which set up a Noise Committee in 1933. The subject has since become one of international concern, as is evidenced by the formation of a League of Nations Commission which held its first meeting at Geneva in June this year, and over which I had the honour to preside.

On the question of what constitutes a noise, it is difficult to generalise. The countryman votes the noises of the city as disturbing to a degree, nor does the townsman necessarily find a lullaby in the noises peculiar to the countryside. Many offending noises owe their origin to ill-timed activities or pure thoughtlessness. The young person hearing the raucous horn with which a friend announces his arrival has no doubt as to its character: neither has the invalid next door. A hearer is in fact patently influenced by psychological and other factors such as background, environment or force of association. There are those, moreover, who have no hesitation in regarding any sound made by some one else as an objectionable noise, while in contrast there are others who seem quite immune to noise and incidentally behave as if they find silence intolerable. Healthy children obviously revel in noise, at any rate of their own making, and the observation appears to apply to many of a larger growth who are in exuberant health, not excluding the Latin races.

The prejudicial effects of certain extremely noisy occupations on the hearing are recognised, but it would appear that the noises encountered in ordinary everyday life are unlikely to impair the hearing, though there is some evidence that in certain types of work they may adversely affect human efficiency. Most mental workers and particularly mathematicians would agree, I think, that noise is an impossible environment to work in. But while many forthright statements have been made about the effects of noise—and no one would withhold sympathy from those misfortunes whose sleep is regularly violated by noise—the root of the matter is probably that for a good many people noise aggravates rather than initiates psychological distress, being a sort of 'last straw' for the sick, the fatigued, or the highly strung. The emotionally stable, on the other hand, have clearly a considerable power of accommodation and can get so used to certain classes of noise as never to notice them, though, were the noises arrested, they would not only quickly miss them but might even, on occasion, confess to an unexpected feeling of relief.

Without doubt then, while there are noises in the world so inappropriate or outrageous as to raise protest alike from the average hearer, the relatively immune, or the hypersensitive, there are equally many border-line sounds on which we should expect them to express very different opinions. In some recent annoyance tests on motor horns at the National Physical Laboratory, in which some two or three hundred observers were employed, it was interesting to note the divergency of views under like conditions of hearing. There was, it is true, a considerable consensus of opinion in
most cases, but a proportion of the observers would as blithely vote the
noise of a particular horn as very objectionable as others would just as
cheerfully class it as tolerable or agreeable. The experiments, in fact,
supported the view that the appraisement of noise is a matter of personal
opinion; and this aspect is endorsed by the British Standard Glossary
which defines noise as 'sound undesired by the recipient.' Small blame
then if some of us find it difficult to distinguish between noise and certain
modern music.

Complaints against noise are of course an old story, probably as old as
civilisation itself. While the acoustic conditions in the Ark do not appear
to have been put on record, there are numerous later Biblical references
to noise: Moses speaks of the 'noise of them that sing,' David refers to
'the noise of water spouts' and elsewhere enjoins us to 'sing and make
a joyful noise,' while Jeremiah bemoans that 'The noise is come . . . to
make the cities of Judah desolate and a den of dragons.' Juvenal wrote
(A.D. 47) of the cost of buying sleep in Rome owing to the noise of herds
of cattle and rumbling waggons in the narrow winding streets. The
Oxford Dictionary gives a reference to 'noyse' dating from 1297: 'Of
trompes and of tabors ye sarazins made here so gret noyse that cristinemen
destourbed were.'

The clatter of the medieval town provoked restrictive regulations;
we find embargoes on nocturnal horn blowing and wife beating in
Elizabeth's reign. The tumult of the streets is well illustrated by a
picture painted by Hogarth in 1741. In some towns in Germany noisy
occupations were zoned, though it is on record that Christian Thomasius
(born 1655) objected to the privilege of the learned professions of driving
from the neighbourhood noisy craftsmen, e.g. blacksmiths and musicians:
he held the view that those living in a city should accustom themselves
to its noise. Frederick the Great's famous and unsuccessful protest
against the noise of the Mill of Sans Souci will be recalled. A hundred
years ago, Jane Austen was graphically describing the traffic bedlam of
Bath. Complaints from City churches of the noise of stage coaches were
common in those days; many of us are of course well aware of how
noisy steel tyres and horse shoes can be on cobbles or stone or granite
setts, and how great was the measure of relief which came with the
introduction of the pneumatic tyre.

The Measurement of Noise.

It is common knowledge that most noises are complex in character,
containing a variety of components which may be distributed over the
entire auditory ranges of frequency and intensity. Such a physical
constitution lends itself to objective measurement and analysis, but there
are, in addition, subjective factors of prime importance to the listener,
viz. pitch, timbre and loudness, and these sensations are not readily
appraisable. Experience indicates, however, that while the composition
of a noise is not to be ignored, sheer loudness is the determining factor in
most cases of annoyance caused by noise, so that the problem largely
resolves itself into the correlation of the sensation of noisiness (as assessed
by the ear) with the associated energy, which can be quantitatively measured by physical instruments.

Let us first consider the measurement of acoustical energy. For the purpose, we need an intensity meter, this commonly consisting of a microphone and amplifier together with a suitable rectifier and indicator. Moving-coil or ribbon microphones are sometimes employed, though for fundamental work the condenser or the crystal microphone is preferred despite the lower sensitivity. Whatever the microphone used, it is usually calibrated by direct interchange comparison under appropriate conditions with a standard (pressure) microphone of the condenser type which in turn has been fundamentally calibrated in absolute units by means of either the Rayleigh disc or the pistonphone.

The Rayleigh disc depends for its operation on the tendency of a small thin glass disc suspended from its edge by a fine fibre to set itself at right angles to a sound field. The torsional constants of the system and the degree of deflection of the disc afford the sound particle velocity, the corresponding sound pressure being calculable from the known relations in the field. The measurements are made either in a stationary-wave pipe or in a room with highly absorbent walls.

The piston-phone, which measures sound pressures directly, consists essentially of a small cavity, one face of which is closed by the diaphragm of the standard microphone, the opposite face consisting of a small piston connected to the moving coil of a loudspeaker unit. The amplitude of motion of the piston, when it is set in vibration, is measured optically and enables the corresponding sound pressures in the cavity to be calculated.

So much for intensity measurements. As regards the associated loudness levels, we turn to auditory diagrams of the ear, such as those of Fletcher and Munson (1933). The various loudness contours for pure tones of different frequencies show that while loudness and energy are manifestly related, the two do not normally keep in step, particularly for notes of very high and very low frequencies. At feeble intensities, the ear exercises pronounced selective preference for notes of medium frequency and it is only at high intensities that equal increments of energy produce even approximately equal increments of loudness. Furthermore, the thresholds of hearing are much higher for high and low frequencies, so that the corresponding ranges of intensity with which the ear can deal, are more restricted than for notes of medium frequency. The situation is worsened in the case of complex sounds or noises since the loudness is affected by their character, there being in general no simple relation between the loudness of a noise and the energy-loudness characteristics of its several components. It is evident that an energy meter, such as a microphone system, cannot unreservedly be used as a direct measurer of loudness.

The Decibel and the Phon.

The next step in the measurement of noise is to equip ourselves with units and standards of loudness. In this connection, we have to cater for the enormous intensity range of the ear, particularly for notes of medium
frequency, where the greatest intensity that can be tolerated (the threshold of pain) is some 10 million million \(10^{13}\) times that corresponding to the threshold of hearing. In such circumstances, we turn, as always, to a geometrical rather than an arithmetical scale, and the unit adopted for the purpose is the bel, which is a ratio signifying a 10-fold increase in intensity, power, or energy. Two bels signify a 100-fold increase, three bels a 1000-fold increase, and so on.

Equipped with such seven-league boots, and starting at a zero approximating to the threshold of hearing, we can traverse the entire auditory intensity range for a medium-frequency note, in as few as thirteen geometrically progressive steps. But the steps are too big for practical convenience, and so it is usual to speak of a range of 130 decibels, which provides a serviceable energy scale. Arithmetically, a decibel (db) denotes approximately a \(5/4\) energy increase (i.e. antilog \(1/10\)), two decibels a \((5/4)^2\) increase, three decibels a \((5/4)^3\) = 2-fold increase, \ldots 10 decibels a \((5/4)^{10}\) = a 10-fold increase, i.e. a bel. More generally, two similar sounds of intensities \(I\) and \(I_0\) and corresponding acoustical pressures \(p\) and \(p_0\) are said to differ in intensity by \(n\) decibels when

\[
\begin{align*}
\log_{10} (I/I_0) &= n/10, \\
\log_{10} (p/p_0) &= 2n/10 \\
\end{align*}
\]

If \(I_0\) or \(p_0\) corresponds to some selected zero, then \(n\) becomes the number of decibels above that zero level.

Thus provided with an acoustical intensity scale, we can proceed to set up a loudness scale which is based on the accepted ability of the average individual to compare and match loudness. To this end (just as in photometry we make use of a standard candle) we need a standard sound, and for the purpose a pure reference tone is chosen which, on the British Standard Scale, has a frequency of 1000 cycles per second. We also require a zero of loudness at or near the threshold of hearing, and this is arbitrarily adopted as corresponding to a pressure of 0·0002 dyne per sq. cm. If now we operate the reference tone by successively increasing decibel steps of energy, the associated changes of loudness are expressed in numerically identical steps on a scale of phons. That is, if the reference tone is excited by an intensity of \(n\) decibels above the zero, the loudness is \(n\) phons. The equivalent loudness of any other sound or noise is evaluated by matching it by ear under specified conditions against the suitably adjusted reference tone, the numerical value of the latter in phons then giving the equivalent loudness of the sound to be measured. Thus by this procedure we have set up a subjective scale of equivalent loudness, the unit being the phon.

It happens that a phon corresponds roughly to the smallest difference of loudness which can be detected by alternate listening, in the case of a sound of medium frequency and moderate loudness. Experience shows, too, that for many loud noises of common occurrence the loudness level in phons is approximately equal to the intensity level in decibels—a convenient relation for many purposes.

A number of different zeros of loudness have unfortunately been employed in the past, e.g. 1 millidyne per sq. cm., which results in
numerical values of loudness some 14 phons less than with the British Standard zero. In Germany the phon is based on a zero of 0.0003 dyne per sq. cm. which is equivalent to a 4 db. difference from the B.S. zero. As, however, a different method of listening is employed, the slight discrepancy between the two scales is not known exactly. The American scale agrees with the British, except that in the States it is customary to use the decibel not only for expressing intensity measurements, but also for loudness levels, it being implied in the latter case that the decibel figure quoted refers to the energy level (above the arbitrary zero) of the standard tone when it matches the sound to be measured. As already mentioned, the British Standards Institution recommends that for greater clarity the decibel should be restricted to energy ratios; and in its definition of the phon, the Institution kept open the way for eventual international agreement on the unit of equivalent loudness.

Happily such agreement came about at an international conference held in Paris last July, when it was unanimously agreed that the decibel and the phon should be adopted respectively as international units of intensity level and equivalent loudness, full agreement being secured on questions of the reference tone (1000 cycles per second), the reference zero (0.0002 dyne per sq. cm.) and the technique of listening. All these matters are in accord with the definitions in the acoustical glossary of the British Standards Institution.

The phon, which has already proved of great service in many classes of noise measurement in this country, came in the nick of time to meet the present demand for noise abatement: the ability to measure is of course vital to such a movement. I may perhaps refer to the public interest which was excited when the decibel and the phon were introduced into everyday language. Mr. Punch made play with the decibel, anxiously enquiring 'how many decibels it took to talk the hind leg off a donkey'; while W. R. in the Observer was moved to welcome the phon in the following terms:—

'Hail! newest unit, welcome to the host  
Of ergs and amperes, kilowatts and therms,  
Best of the lot, you shall be valued most  
Among these unintelligible terms.

For you alone can make men realise,  
In figures plain, the awful din they make,  
So that at last some genius may devise  
A means of curbing it, for Reason's sake.'

The experimental realisation of the fundamental scale of phons is one for the standardising laboratory, as will be appreciated from the subjoined definition of the phon taken from the British Standard Glossary of Acoustical Terms and Definitions, 1936 (No. 661). For example, the specification of a free progressive wave postulates an acoustical environment corresponding to infinite space, which in practice can only be conveniently simulated by placing the 'normal observer' (in practice
the average of a trained group of observers) in an experimental chamber with highly absorbent walls. Furthermore, while it may be possible in the fundamental evaluation of the equivalent loudnesses of sounds or noises in phons, for certain sources to be accommodated in the lagged test chamber, it may not be practicable in other cases, whether on the score of size or the impossibility of quickly starting and stopping the source, so as to permit alternate listening with the reference tone. In such cases, the sources have to remain outside the chamber and the sounds are transmitted at will to the observer inside by means of a micro-
phone and loudspeaker system. A closer specification of the measuring technique is at present being developed by the British Standards Institution.

'Phon (B.S.). A unit of equivalent loudness, defined as follows: The standard tone shall be a plane sinusoidal sound wave train coming from a position directly in front of the observer and having a frequency of 1000 cycles per second. The listening shall be done with both ears, the standard tone and the sound under measurement being heard alternately and the standard tone being adjusted until it is judged by a normal observer to be as loud as the sound under measurement. The intensity level of the standard tone shall be measured in the free progressive wave. The reference level shall be taken to be that corresponding to an R.M.S. sound pressure of 0.0002 dyne per sq. cm. When, under the above conditions, the intensity level of the standard tone is \( n \) decibels above the stated reference intensity, the sound under measurement is said to have an equivalent loudness of \( n \) phons (B.S.).'

Reference may here be made to the criticism to which the phon scale has been subjected in some quarters, in that it does not interpret numerically one's sensations of loudness, a phon near the top of the scale admittedly signifying a much bigger step than it does near the bottom. Some workers in this country and the States have accordingly attempted to set up a subjective scale of loudness units in which the assumption is made that fractional estimation by an observer is possible, so that, for example, it is claimed he can say when one sound is twice as loud as another. A comparison of the mean scale so derived with the phon scale suggests that such an estimated doubling of loudness is equivalent to an increase of about 10 phons for moderately loud sounds. While, however, the scale of equivalent loudness in phons may not be subjectively ideal, it does rest on sound physical foundations and accepted subjective principles. Furthermore the connection of the phon scale with the decibel scale is of great practical value to the acoustical engineer, for example in dealing with the transmission of air-borne sounds by walls.

**Noise Meters.**

It will be appreciated that the experimental conditions laid down for the fundamental evaluation of sounds or noises in phons, are rarely likely to be available for noise measurements in everyday circumstances, and
simpler techniques have accordingly been evolved which make portable noise meters feasible for field conditions. There are two main types of meter on the market, namely subjective meters, which were first developed by Barkhausen, and objective meters utilising a microphone and amplifier system. At the National Physical Laboratory, the calibration of such meters in phons is effected in lagged chambers by means of sounds of known phon values, for example, pure tones of various frequencies, and gramophone, synthetic or other reproductions of a variety of noises such as the meter may be called upon to measure in practice. The British Standards Institution is at present engaged in developing specifications of noise meters designed to conform to the B.S. scale of phons, and, in the meantime, purchasers of noise meters would do well to demand a calibration certificate by an accepted testing authority.

(i) **Subjective noise meters.**—Subjective noise meters depend on the equality matching of the loudness of a noise, as heard by the ear, with a reference tone (usually a pure tone of specified frequency and of graduated intensity) as heard in a telephone earpiece held tightly against one ear. The reference tone may be produced by an electric buzzer, valve oscillator or other means, various frequencies (e.g. 1,000 or 800 cycles per sec.) or mixed tones being used in commercial instruments. The usual Barkhausen technique involves simultaneous listening of the noise and the reference tone, but experience indicates that inconsistencies which are found to arise in aural measurements under such conditions are largely resolved when the two sounds are heard alternately for periods of not less than a second. Such a technique has been facilitated by Churcher in a subjective meter employing two earpieces, so that either the noise or the reference tone can be heard in turn using both ears simultaneously.

Subjective meters are useful for certain purposes, but the aural judging of equality of loudness of the reference tone and of a noise very different in character is not always easy. Observers are found to differ widely in their judgments and the same individual is not always consistent. The accuracy of appraisal of a single observer is normally low (say 5 phons) and a team of trained observers is essential for higher precision (say 2 phons). In the case of unexpected or single impulsive sounds, the aural assessment presents great difficulties to the average observer.

(ii) **Objective noise meters.**—The problem of the designing of objective sound and noise meters, which has received much attention both in this country and abroad, is of considerable complexity. The ideal aimed at by objective meters is to be able to measure every type of sound and noise on the subjective scale of phons, that is to simulate the selectiveness and response of the average ear in all circumstances.

The various objective meters on the market all consist essentially of a pressure microphone connected to an amplifier provided with calibrated control, followed by some type of rectifier and an output indicator. As a first essential, objective meters are constructed to give the same reading for a range of steady pure tones which sound equally loud to the ear whatever the frequency. This is achieved by introducing into the amplifier electrical networks designed to modify the shape of the frequency characteristic so that it imitates the ear sensitivity at selected loudness
levels. If the network is omitted, the meter measures intensity levels. Objective meters should be further designed to simulate the salient characteristics of the ear in dealing with either steady or impulsive sounds. For example, the ear does not record full strength until a steady sound has persisted for about one-fifth of a second, and in the case of pulsating sounds, the inertia of the instrument has to be of the right order to give readings corresponding to average aural appraisement.

The practice has developed in certain countries of constructing objective meters to arbitrary specifications (which include quadratic rectification and certain instrumental requirements), the meters being ostensibly designed to deal with pure tones and certain common types of sound. The readings, which are sometimes referred to as 'sound levels,' are not claimed as conforming necessarily to subjective equivalent loudnesses. Experimental calibrations of such meters show, however, that while they may give results in reasonable agreement with subjective measurements in the case of steady pure tones or other sounds, they afford readings in the case of particular types of intermittent noise (such as certain machinery or traffic noises) which are considerably lower than equivalent loudnesses as measured by the fundamental method. It was agreed at the international acoustical conference in Paris last July that it was undesirable that a meter should be used for measuring the equivalent loudness of sounds unless it has been shown, by calibration in an accepted standardising laboratory, to give results, for the particular sounds in question, which are in reasonable accordance with the subjective scale of phons.

The difficulty of dealing with intermittent sounds can, it appears, be met by replacing the quadratic rectifier by one of the leaking peak variety. Portable objective meters of this type have been designed by Davis at the National Physical Laboratory and independently in Switzerland. The former instrument has recently emerged successfully from a prolonged series of tests on the equivalent loudness of a wide variety of noises, including continuous, warbling, and impulsive short-duration sounds (recurring at rates of from 12 to 50 per second), as well as the noises of motor cars, motor cycles and motor horns. For moderate or loud noises, the measurements were found to agree more closely with the average aural appraisements of a group of observers than did those of any one of the observers. The leaking peak rectifier enables the rates of integration and decay to be adjusted empirically so that the meter simulates the response of the ear in giving higher results for rapidly recurring impulses than for slowly recurring or single impulses. For example, the loudness of a single impulse may be nearly 10 phons less than if 30 to 50 such impulses occur per second. Experiments designed to formulate a specification of the physical behaviour of the meter are not yet complete and, at present, the meter is not designed for levels lower than about 65 phons.

While, however, a 'universal' objective meter is not yet specifiable, there can be little doubt that the future of sound or noise measurement, from a practical point of view, lies with the objective meter. Even in its present state of development, its practical convenience often outweighs its limitations. It is free from personal bias, rapid in action
and direct reading, and can be put into the hands of an untrained observer. Furthermore, as a dial instrument, it is well adapted to the enforcement of regulations or specifications.

**The Analysis of Noise.**

The wave-form of the microphonic current of a sound can be readily displayed by means of a cathode-ray oscillograph, but the analysis of such wave-forms is usually troublesome, and the composition of a sound or noise is determined more conveniently by other means. The methods of spectrum analysis in optics are not convenient in the case of sound, by reason of the much longer wave lengths of sound and their wider range, the visible spectrum covering a range of only about one octave, whereas the range of sound to which the ear responds extends over about ten octaves. A diffraction grating of the order of size of a garden fence would in fact be required to deal directly with a normal acoustic spectrum.

For the analysis of sound, the earlier experimenters used acoustical resonators which were tuned to respond to the different components present in the complex sound. In present-day methods, the oscillatory pressure variations which constitute the sound are first converted, by means of a microphone, into corresponding electrical oscillations; and the problem is reduced to the analysis of a complex electrical oscillation, a process which may be effected by tuning or filtering circuits or by the use of a search or heterodyne tone. Such filters may be either of the high-pass or low-pass type, or alternatively may be arranged to pass bands of frequencies extending over, say, an octave or a fraction of an octave. This latter method is particularly valuable in the case of noises which are not of a steady nature or composition, for example, traffic noise.

Steady sounds or noises readily lend themselves to analysis and yield typical line spectra, but the matter is less simple with transients, that is, acoustical impulses which start suddenly and die away rapidly. Examples of transients are speech (and in particular certain consonants like p and b), whip cracks, rifle shots, blows, footsteps, hand-clapping, percussion instruments, e.g. the piano, drum, and most musical instruments. All such sounds prove to be largely of the band-spectrum type with superposed line spectra and nearly all contain very high frequencies.

Sound analysis may be of particular service in studying machine noises as a means of tracking the source of major components. Synthesis of sounds is sometimes resorted to for particular purposes. Much progress has been made of late in the commercial development of instruments for acoustic analysis and synthesis. Here is an analyser which will almost instantaneously reveal the composition of a noise, while here also is a synthesiser, kindly lent me by Messrs. Comptons, the famous organ builders, in which pure harmonics of controllable intensity can be so blended as to simulate, for example, church bells with a fidelity which is very arresting.

**Noise-level Measurements.**

In connection with problems of noise abatement, the National Physical Laboratory has made measurements and analyses of many noises of very
varied origin. The positions which some of these noises occupy in a scale of phons are shown in Fig. 1, the upper half of which includes various noises whose abatement would be acceptable in many circumstances. This is illustrated by the homely test which most of us apply as a test of background of noise, i.e. the ease with which conversation is possible. At 60 phons, conversation is 'comfortable'; at 90 phons, difficult; and at 110 phons, virtually impossible.

Among the noise problems on which the Laboratory has been consulted in recent years, are the mitigation of the noises associated with aeroplane-cabins and engine-testing factories, trains, ships, tube-railways, buses, motor horns, pneumatic drills, printing works, transformer sub-stations, cathedrals, assembly halls, business offices, flats, miniature rifle ranges, building operations, and so on. Assistance is also being given in connection with the Home Office experiments on air-raid warnings.

Approximate loudness levels of common noises.

B.S. Loudness scale of phons.

- **Proximity of aeroplane engine**
- **Proximity of riveting or loud pneumatic drill**
- **Proximity of loud motor horn**
- **Noisy lorry (50 m.p.h.) at 20 ft**
- **Quiet car (50 m.p.h.) at 20 ft**

<table>
<thead>
<tr>
<th>Noise Description</th>
<th>Phons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loud conversation</td>
<td>70</td>
</tr>
<tr>
<td>Quiet conversation</td>
<td>60</td>
</tr>
<tr>
<td>Quiet electric motor at 5 ft</td>
<td>50</td>
</tr>
<tr>
<td>Tearing of paper at 5 ft</td>
<td>40</td>
</tr>
<tr>
<td>Ticking of watch at 5 ft</td>
<td>30</td>
</tr>
<tr>
<td>1000 cycles per sec; zero 0.0002 dyne per sq cm.</td>
<td>0</td>
</tr>
</tbody>
</table>

Near threshold of pain

In printing press room

In busy machine shop, pump house etc.

In tube train; window open

In busy typing room

In express train; window open

In busy main street

In quiet saloon car (30 m.p.h.)

In suburban train; window open

In quiet residential street

In very quiet room

In extremely quiet room

Near threshold of hearing

Fig. 1.
The loudness of a noise depends of course on its remoteness and to a less degree on its environment. The inverse-square law appears to be followed fairly exactly in the open for average sounds such as those of motor vehicles. In a room or a tunnel, the law does not hold and a noise sounds louder than it would outside, owing to the building up of the sound level by multiple reflection. Similar conditions prevail in a narrow busy street and contribute to the noise discomfort of the occupants in the upper stories, though to a pedestrian, the noise of, say, a passing car is but little louder than in an open space. Incidentally, drivers of cars are familiar with the sudden access of high-pitched components from the engines, exhausts or tyres of their cars as they pass reflecting walls or fencing or even minor way-side objects such as tree trunks or telegraph poles.

One has also to remember that the path of a sound may appreciably modify its composition. For example, the high-frequency components may be abnormally reflected or absorbed as compared with lower notes which tend to pass through or round obstacles. Even in the open, a hedge row or a barrage of trees may, to a limited extent, so serve as a muffler of traffic noise. The high-pitched components of a sound may further be selectively enfeebled in passing over different types of ground, for which the sound absorption may be three or four times as much for high notes as for low. To judge by experience, the absorption figures for newly fallen snow must be rather high, though I am not aware that they have been measured. High-frequency components may also be selectively absorbed by the air itself if it is humid. Knudsen has shown that the effect is due to interaction between the oxygen and water molecules, the nitrogen playing no part. Incidentally, he estimates that if we lived in an atmosphere of oxygen at a humidity of about 20 per cent., the high notes of the violin and piccolo would be completely inaudible 50 yards away.

Noise on the Railway.

The background of noise (70–90 phons) which prevails in the compartments of most express trains is normally so near the borderline that, even with the windows closed, conversation between 'diagonal-wise' passengers, though possible, is not 'comfortable.' The noise patently originates from the rapid intermittent pounding of the steel tyres against irregularities in the steel rail, largely supplemented by recurrent rail-joint impacts. Much of the noise is of low pitch, and, as simple observation shows, it enters the coach partly through the floor, but mainly through the glass of the windows. The remainder of the noise, which is of somewhat higher pitch and more directional, forces its attention on us whenever the train passes a reflecting surface such as a platform, wall, or another train, on which occurrence, the normal background of noise in a compartment is supplemented by a burst of higher-pitched noise deflected through the windows. The conditions are aggravated (by as much as 10 phons) when a train is passing at high speed under a bridge or through a cutting or tunnel, so that conversation then becomes difficult.

An obvious palliative for rail-joint tap takes the form of longer rails.
120 feet lengths are now being employed on the L.N.E.R., while it is stated that lengths as long as 2,700 feet have been welded together on German main lines. Rail monocars with pneumatic tyres, now used for certain local services in this country, extinguish rail noises to such a degree as to be almost uncanny, particularly from outside. Express-train travel in this country may be experienced in its most comfortable form on such trains as the 'Silver Jubilee,' with its generous use of absorbent in the coaches, permanently-closed double windows and air-conditioned ventilation, conversation being readily possible at all speeds.

Whatever the acoustic difficulties may be in trains above ground, they are multiplied many times in an underground railway system. The London Passenger Transport Board have achieved considerable success in their experiments on the acute problem of noise which is presented by the tube railways. Rail-joint noise is lessened by the use of 90 feet instead of 42 feet rails, which are then welded together in position. Further improvement comes from the employment of a rail-grinding car, which removes dents and imperfections from the rails and leaves them smooth. In addition, the experiment is being tried of continuous shields, made of asbestos and other materials, which project from the sides of the tunnel almost to the footplates of the train, so trapping and absorbing the noise coming from underneath.

It is stated that these several measures result in an 80 per cent. diminution of the noise, which presumably corresponds to a reduction of about 7 phons. Incidental noises such as wheel, gear and motor noise are reduced by the use of asbestos pads. Asbestos brake-blocks advantageously replace cast iron, while thicker glass windows help to reduce rattle. Seats of absorbent rubber or similar material, instead of cane, assist in lowering the noise level particularly in relatively empty coaches. A persistent type of noise in tube railways is the grating of wheel flanges in passing round sharp curves.

**Noise in the Air.**

The degree of silencing which has been achieved in aircraft serves as an outstanding illustration of what can be done in the case of a gross noise problem under conditions so discouraging that only a few years ago it was commonly regarded as unlikely to find a satisfactory solution. It was important that ways and means should be found, for the noise of the engine had become the most serious deterrent to aeroplane travel, conversation in the cabin being quite impossible.

Since 1929 an extensive programme has been undertaken by the National Physical Laboratory for the Aeronautical Research Committee of the Air Ministry. There are three main sources of aeroplane noise: propeller noise, exhaust noise and engine clatter. The attack on the problem came in a variety of ways, for example, by using propellers with lower tip speeds, by better positioning of the engine exhausts, by more effective exhaust silencing, by enclosing the engines so as to reduce engine clatter, by increasing the relative isolation of the engine and cabin, by a better placing or shielding of the cabin with reference to the propellers,
by constructing cabins of double walls containing a suitable filler, by the
damping of 'drumming' panels, etc., and by increasing the amount of
absorbent in the cabin. Measurements have been made in aeroplanes
in flight and on the main individual sources of noise under experimental
conditions.

The present position is that the noise in the passenger cabins of some
of the latest air liners or flying boats is little more than that in a train.
This is very well for the passengers; from the point of view, however,
of those who live near aerodromes or on busy air routes the noise of air-
craft is still a nuisance which awaits a solution.

Noise on the Road.

(i) Ministry of Transport tests.—The growing volume of road traffic,
and the ever-increasing speed and acceleration of individual vehicles, are
potent contributory factors to the problem of road transport noise.
There have, it is true, been certain counterbalancing changes, to wit, the
steady gain in quietness of the newer models of the motor bus and motor
coach, and the introduction of the trolley bus in place of the much noisier
tram car. But these are only drops in the bucket. Backed by the force
of public opinion the then Minister of Transport, Mr. Hore Belisha, who
proved himself a great ally of quietness on the road, set up in 1934 a
Departmental Committee for the purpose of studying the question of
motor-vehicle noises. The Committee included representatives of the
motor and motor-cycle industries; and as Chairman of the Committee,
I hope I may be permitted to refer to some of its proceedings and
recommendations which are contained in the three interim reports so
far published. These reports, which may be consulted for fuller informa-
tion, are based on an elaborate series of tests, comprising many thousands
of observations, which were carried out on behalf of the Committee by
National Physical Laboratory.

(ii) Tests on new motor vehicles.—The first two reports deal with tests
on a representative selection of nearly 100 mechanically-propelled
vehicles, comprising saloon motor cars, sports cars, motor cycles, goods-
and passenger-carrying vehicles, most of which were kindly lent by the
industry. It was decided to begin the work by a survey of newly manu-
factured vehicles, both of home and foreign origin, which were intended
to operate on the roads in this country.

After careful consideration, the Committee decided to confine their
first attention to the 'overall' noise of vehicles, as representing the aspect
of major public interest, and one which might be expected to afford,
without undue delay, information which would serve as a trustworthy
basis for possible legislative action. No systematic attempt was made to
study the composition of the noise, the major components of which in-
clude those from the engine, transmission and exhaust, although a partial
separation of the 'fore' and 'aft' components was possible without
difficulty. It was rather felt that further steps could best be left to

1 "Noise in the operation of mechanically propelled vehicles." O.H.M.S.
1935, 1936 and 1937.
the initiative and efforts of the industry itself which, as a whole, merits high praise for its substantial contributions to the silence of motor vehicles, for example the flexible mounting of engines, the counter-balanced crank shaft, silent gearing, the straight-through type of exhaust silencer, and the development of car bodies which are sound insulated and sound absorbent. In the matter of both exhaust and general silencing, certain motor car manufacturers have achieved remarkable perfection. It is a notable comment on the success of the general quietening of cars that tyre noise (about 75 phons) has become conspicuous at moderate speeds, especially on particular road surfaces on wet days. Even in the matter of certain motor cycles and sports cars, it must be conceded that their acoustic blemishes have been largely stimulated by a section of the public which happily now finds itself in a small and dwindling minority.

The Ministry of Transport tests were carried out under conditions of both use and abuse, with the object of arriving at a measure of the noise potentialities of a vehicle in the hands of a driver who is prepared, on occasion, to misuse it and so give rise to an objectionably large output of noise, for example, by racing a stationary engine at high speed, or travelling at high acceleration in a low gear.

The Committee, while appreciating that the effect of noise on the human being is partly psychological, satisfied itself that the problem before it was one mainly of loudness, and that the N.P.L. objective noise meter, which was used throughout the tests, provided a trustworthy index of the average noise levels experienced by the observers present.

Measurements were first conducted on stationary vehicles with racing engines. These were followed by tests on running vehicles in various gears at a variety of steady speeds and also when accelerating under full throttle, both on the level and when climbing hills. Each vehicle was driven either by the firm's driver or the owner during the tests, and the goods- and passenger-carrying vehicles were tested fully laden. Some of the tests were carried out on Brooklands Track, others in various parts of Middlesex and Surrey under a wide diversity of favourable and unfavourable weather conditions.

In general, the measurements showed that, omnibus paribus, a vehicle emits most noise at its highest speed, so that the gain in quietness from the imposition of the 30 m.p.h. speed restriction in built-up areas would seem to be worth while. In the case of the tests on cars and motor cycles when running on the level in top gear, the average noise emission at steady road speed was found to increase by about 4 phons for each 10 m.p.h. increment of speed, while at full throttle the corresponding figure was of the order of 2 or 3 phons. In the case of cars or motor cycles, the noise at 30 m.p.h. steady speed was on the average about 5 phons less than when accelerated at full throttle at that speed. It was also established that when a vehicle was travelling at full throttle at a specified speed in a given gear the noise was substantially the same whether the vehicle was accelerating on the level through the instantaneous speed in question, or climbing a hill at the same steady speed.

A few tests were conducted with cars and lorries free-wheeling, i.e. with the engine stopped and the gear in neutral. The loudnesses measured,
which naturally set a limit to the quietness attainable, ranged between 70 and 80 phons at 30 m.p.h.

The noise levels recorded during the various running and racing engine tests extended over a wide range—in round figures, 40 phons, i.e. from 75 to 115 B.S. phons, at a distance of 18 feet sideways or 25 feet to the front or the rear. A consensus of opinion among the observers present at the tests suggested that a transition point between tolerably noisy vehicles and unduly noisy ones was in the region of 90 B.S. phons.

In general, the following conclusions emerged from the tests on new vehicles:

(a) Confirming the common impression, the average present-day 'ordinary' motor car is not oppressively noisy, except at high engine speeds.

(b) Certain 'sports' cars (though not all) are too noisy but can clearly be improved without much difficulty.

(c) Except at moderate steady speeds, many motor cycles make far too much noise.

(d) Certain commercial vehicles are somewhat noisy but could probably be substantially improved without a great deal of trouble.

The Committee were therefore led to make the following recommendations for new vehicles which, while designed to ameliorate traffic noise in all localities, take particular cognisance of 'built-up' areas, in which regions the effects of excessive noise are undoubtedly the most disturbing:

(1) 'No new motor cycle, motor car, heavy motor car or motor tractor, as defined in Section 2 of the Road Traffic Act, 1930, shall be offered for sale or for use on the public highway unless it complies with the requirements stated below, the specified tests of which must be conducted in an open space free from the proximity of buildings, etc.

(a) 'Normal running test.—When the vehicle is running at a road speed of 30 m.p.h. (or at such lower maximum speed as is attainable by the vehicle or is legally prescribed for it) with the engine at full throttle and using the gear preferred by the driver, then the loudness at a point distant laterally 18 feet from the midpoint of the vehicle shall not exceed 90 phons (B.S.). Measurements shall be made on each side of the vehicle and the mean taken. The running conditions specified may be realised either on the level or on an incline, using appropriate acceleration, braking, loading, etc.

(b) 'Racing engine test.—When the vehicle is stationary and the engine is running at the speed at which it would give its maximum power, the loudness at a point distant 25 feet behind the open end of the exhaust pipe shall not exceed 90 phons (B.S.).

(2) 'A latitude of 5 phons on the above noise limits shall be allowed for a period of two years on the following classes of vehicles:
'In respect of the "normal running test": motor cycles, heavy motor cars and motor tractors.

'In respect of the "racing engine test": motor cycles.

'After two years the normal limits shall prevail.

(3) 'As it is obvious that finality has not been reached in the art of quietening mechanically propelled vehicles, the Minister should reserve the right to amend in the future the above noise limits in the light of further developments.

(4) 'The Minister should by regulation make it an offence to cause or permit the engine of a stationary vehicle to be run at excessive speeds.'

With regard to cars, both of the ordinary and sports types, there can be little doubt that conformity with the suggested limits is either already attained or readily can be. The difficulties are doubtless greater in the case of motor cycles and commercial vehicles, where it may be that an acceptable degree of quietness is only attainable by a sacrifice of power and an increased cost. It was felt, however, that given time the problem was not insoluble, and a tolerance period of two years was accordingly suggested to meet the situation.

Polar diagrams which were obtained by exploring the sound distribution round a vehicle, indicate that ordinary cars and commercial vehicles owe their loudest noise to their engines, while in the case of motor cycles and certain sports cars, the loudest noise is in the direction of the exhaust pipe. Extreme examples of the latter occur, and it was to meet these that the racing engine test was introduced, as such cases may not reveal themselves in the lateral noise measurements associated with the normal running test.

As regards the racing engine test, the engine speeds proposed are those at which the maximum power is developed, and though the speeds are high, they are not abnormally so. Still higher engine speeds may produce a considerable increase in loudness—as much as 10 phons—and the Committee felt that such misuse of a vehicle, for example in a quiet street, would be best met by a regulation on the lines of recommendation No. 4.

(iii) Tests on 'used' motor vehicles.—Having thus dealt with vehicles fresh from the manufacturers, the Committee passed on to 'used' or 'old' vehicles, and in their third report published a few months ago they deal with this matter. Experience suggests that the noise from used vehicles will normally be higher than from newly manufactured ones, whether by reason of development in design, or as the result of normal wear and tear, or unsatisfactory maintenance. The ultimate object of the investigation on used vehicles was to study the feasibility of a common noise limit for all classes of vehicles on the roads to-day, irrespective of their age or circumstances of use.

Accordingly a series of tests, on the lines of those in the earlier reports, were undertaken on some 40 representative vehicles, including motor cycles, motor cars and commercial vehicles, of various ages up to 13 years. These tests were supplemented by random observations on some 600
vehicles in normal traffic on a variety of roads, some speed-restricted and others unrestricted.

The results were in general harmony with the previous conclusions, and it appeared that a difference of about 5 phons between new and old vehicles is an all-round representative figure which takes cognisance of the many factors involved such as type, design, power, age and state of repair. The evidence was, however, not sufficiently definite to indicate that the noise was dependent on the age of the vehicles to any outstanding degree.

The measurements on normal traffic on the road were spread over a range of approximately 70 to 105 phons, and from a study of the results, it appeared that a general limit of 95 phons (B.S.) for the various classes of vehicles was a reasonable figure, which would rule out the chief offenders and would not be incompatible with the limit of 90 phons proposed for the tests on newly-manufactured vehicles. If such a limit were brought into force, the Committee was of opinion that the case of vehicles already licensed on the roads could be met by a tolerance period of two years.

The tests indicated that greater progress had been made in the silencing of sports cars than of motor cycles, many of which constitute at high speeds the noisiest traffic on the road to-day. The Committee took the view that the temporary figure of 95 phons suggested for the tolerance period in the case of new motor cycles, should also suffice for motor cycles on the road which are run at reasonable speeds. The Committee therefore submitted to the Minister of Transport the following recommendations dealing with used vehicles:—

(1) 'When a vehicle is used on the public highway the loudness of the noise emitted when measured at a point distant laterally 18 feet from the mid-point of the vehicle, or 25 feet behind the open end of the exhaust pipe shall not exceed 95 phons (B.S.).

(2) 'A vehicle shall be regarded as complying with the above require-
ment if it can pass the following tests: '—

[Here follow the specifications for the 'normal running test' and the 'racing engine test' as for new vehicles (pp. 59 and 60), with the exception that '95 phons' replaces '90 phons'.]

(3) 'The noise limit of 95 phons (B.S.) for vehicles on the public high-
way shall operate in the first case only in respect of vehicles registered on or after the prescribed date, but shall come into general application for vehicles of any age after two years have elapsed from that date.

(4) 'The Minister should reserve the right to amend in the future the above noise limit in the light of further developments.'

(iv) Summary of Ministry of Transport's reports.—To summarise the three reports of the Ministry of Transport Committee, the position is that for the first time in this country a comprehensive attack has been made on the problem of road traffic noise. To this end, loudness measurements, many thousands in number, have been conducted under widely different working conditions, on the over-all noise of some 800 motor vehicles,
both new and old, representing all the main types on the roads to-day. The results (at a distance of 18 feet sideways or 25 feet to the rear) mostly ranged between about 70 and 105 phons (the latter value corresponding to a noisy road drill). The Committee were led to propose simple running and racing engine tests which are associated, under specified conditions, with an 'over-all' noise limit of 95 phons, which is roughly equivalent to the noise in a tube train) for all vehicles in use on the road, and of 90 phons for new vehicles leaving manufacturer's works.

The adoption of these noise limits, while making very moderate demands on most types of vehicles would, by ruling out the arch offenders, constitute a substantial contribution to the amenities of the road. In the meantime, the industry, which has already discovered that 'silence is saleable,' has the matter well in hand and indeed it is not unlikely that future developments will not only enable manufacturers to meet the proposed requirements with comparative ease, but may indeed enable the limits to be lowered as time goes on. Certain types of vehicles, such as most ordinary cars, are already agreeably quiet, but others, notably motor cycles, have lee-way to catch up; and the Committee has accordingly suggested breathing space in the shape of periods of grace to meet these and other aspects of the problem of noise as it is on the road to-day. The Committee's task has not been easy, but I trust the limits of noise which it has proposed will, in one way or another, help to ensure a standard of acoustical decency on the roads of this country.

Following the publication of the Committee's reports, the Minister of Transport received assurance from the manufacturers of motor cycles and sports cars that they will not in future put on the market any new vehicle the noise of which could be regarded as offensive. To assist the motor industry in this laudable object, the Ministry recently set up four noise-testing stations in different parts of the country. At each of these stations an N.P.L. noise meter is installed, and manufacturers are enabled to submit types of their products and so ascertain for themselves how the noise levels compare with the limits proposed.

The whole question will be further facilitated when the simplified objective noise meter, which has recently been developed by the National Physical Laboratory for the Ministry is put on the market. Such meters, which will be checked against the Laboratory standard meter, should, when available in quantity, be of great assistance at such time as it may be decided to bring into force regulations for dealing with noise on the road.

As regards the outstanding problem of the abatement of motor-cycle noise, I may mention that the British Cycle & Motor Cycle Manufacturers & Traders Union Ltd., together with the Institution of Automobile Engineers, have recently instituted a programme of research which is to be carried out largely at the National Physical Laboratory.

(v) Motor horns.—Motor horns, if unduly loud or improperly used, have come to be regarded as a very unnecessary nuisance on the road. In this connection it is generally appreciated that the Ministry of Transport's beneficent suppression of horn hooting at night has not only led to no increase in accidents but has taught many people to drive more
quietly in the day time also. Most of us have come to agree that a strident horn rarely, if ever, makes for safety but more frequently leads to indecision or fear on the part of other road users. The National Physical Laboratory has carried out measurements on motor horns for the Departmental Committee of the Ministry of Transport, with the object of determining the scope and effectiveness of such warning devices and, if possible, of correlating annoyance with some measurable physical factor. The report of the Committee is not yet available. Incidentally it is common experience that a reasonable driver seldom finds it necessary to employ a horn at all, a doctrine to which it is evident that Paris and some other Continental cities do not subscribe.

(vi) Pneumatic road drills.—Before leaving the subject of road noises I ought to refer to that sporadic producer of undue noise—the pneumatic road drill. Much attention has been given to the question of its silencing: possibly the problem of impact silencing will remain until rotary drills come into use. That there are grounds, however, for believing that some progress is being effected in regard to exhaust silencing would appear from some comparative tests carried out last year under the auspices of the Westminster City Council. Equivalent loudness measurements made by the National Physical Laboratory gave an average figure of 102 phons (B.S.) for the unsilenced drills, while the corresponding figures for the silenced drills ranged from 91 to 101 phons, the lower values thus bringing the noise nearer to that of general traffic noises in a busy street, say 80 phons. Unfortunately it appeared that, roughly-speaking, the drills making the least noise took the longest time to break a given amount of concrete, though the relative skill and experience of the different operators and labourers in the competing teams must not be lost sight of in comparing the efficiencies of the different drills.

The Abatement of Noise.

While in some European countries there are now severe legal prohibitions against noise, the position in this country is rather that of legally identifying a noise with a nuisance. Under the provisions of the Public Health Act of 1936, it is the duty of a local authority, if satisfied of the existence of a nuisance, to serve a notice requiring its abatement, and, in default, to take proceedings in court for abatement or prohibition of the nuisance. There are, moreover, numerous precedents in local Acts already in force, according to which a noise nuisance exists if any person makes or causes to be made any excessive or unreasonable or unnecessary noise which is injurious or dangerous to health. Such noise nuisances often arise from plant and machinery which are operated during the night or early morning, but there are other circumstances which appear to demand a working definition of a noise nuisance. It should be added that if a noise occurs in the course of any trade, business or occupation, it is a good defence that the best practicable means of preventing or mitigating it, having regard to the cost, have been adopted. As regards the noise of motor vehicles, much information concerning legislation will be found in the First Report of the Ministry of Transport Departmental Committee on Noise.
In the meantime the law is doing its best. A London magistrate was recently courageous enough to describe that which is emitted from a Scotsman's bagpipes as noise. A stipendiary ruled not long ago that a violin and piano-accordion are 'noisy instruments,' and so is the human voice, but only if used in a concerted piece with other instruments. A firm of Galton-whistle manufacturers advertises 'silent dog-whistles' and so avoids any possibility of legal interference.

There are two guiding principles when the question of noise abatement is being considered. The one is that the degree of abatement of a noise in a particular locality need be no more than will conform to the background of noise which obtains in that locality. The other is that in a medley of noises, the loudest must be tackled first to achieve any appreciable benefit, after that the next loudest, and so on. This is illustrated by the fact that if there are two similar components and one is 10 decibels less intense than the other, the weaker one will contribute only half a phon to the over-all loudness.

I am reminded that to illustrate the somewhat meagre additive effect of two equally intense sources, I was guilty a few years ago of perpetrating an analogy based on crying twins. I now realise that the subsequent march of events demands a more extended treatment, and so, for the benefit of those who may be interested, I should add that 'quins' chattering simultaneously are 7 phons louder than one by herself, and that the corresponding figure for 'quads' is 6 phons, triplets 5 phons, and twins 3 phons.

The first line of attack on noise abatement, and in general much the most effective and economical, is to tackle an objectionable noise at the source, and find the best means of reducing the output as much as possible. The next step, possibly as a confession of failure, is to find a feasible method of confining or 'smothering' the noise in the place where it is generated. In either case we turn to the engineer for help, and we may anticipate that he is likely to be the more interested if he can see a potential demand from the public. Fortunately the public is becoming sufficiently noise-conscious to query the need for noises which it stigmatises as a nuisance, so that there is now a goodly list of 'silent' appliances in everyday life, though as regards many commercial machines and processes, it is realised that the millennium is not yet and we must put up with second-best expedients for the present.

The path of a noise in its journey from source to hearer, may be either via the intervening air, or via a sequence of solid materials or structures. Experience has shown that the two effects require very different remedies for abatement. The study of the general problem of noise transmission is more complex than might be imagined, and some of the major difficulties are not as yet completely resolved. For the practical elucidation of the various factors involved, specially designed 'sound-proof' laboratories, such as those at the National Physical Laboratory, have proved to be necessary. Parenthetically, it may be mentioned that the N.P.L. acoustics laboratory, since its erection four years ago, has been so fully engaged in transmission and absorption work, mainly for the architectural profession and the building industry, that extensions are
now in hand and should be available for use by the end of the year. Much research work on building acoustics is also being carried out for the Ministry of Health in connection with slum clearance, and for the Architectural Acoustics Committee of the National Physical Laboratory and the Building Research Station.

To revert to the case of a non-suppressible noise, if most of the noise is transmitted by air, the best remedy, should circumstances render it practicable, is some sort of sound-proof enclosure, the design of which may need careful attention both as regards weight and discontinuity of structure. There is, of course, no such thing as a sound-proof material, and success in sound insulation is largely a matter of design.

Certain large-scale operations may require ‘sound-proof’ buildings to mask them, the doors and windows of which should be heavy and close-fitting and preferably situated on the side remote from that where the noise is liable to be regarded as a nuisance. Doors and windows, particularly high windows and skylights, may require to be doubled and, in extreme cases, it may be necessary to employ double walls mounted on independent foundations. Buildings in which noisy operations are carried on should, if possible, be put under the lee of larger buildings, which may afford advantageous shielding to the locality. In the interior of noisy buildings, it is usually beneficial to the workers to divide groups of noisy machinery, as far as may be possible, into smaller units, each in its own enclosure. Appreciable benefit may also result from lining walls and ceilings with acoustical absorbent, so preventing the noise level from building up unduly.

In the case of structure-borne noises, the remedy is discontinuity somewhere in the structure either in the form of an air gap or as resilient material, for example, under the foundations of noisy or vibrating machinery.

As an illustration of the abatement of extreme noise, near a residential area, reference may be made to the new Alvis works at Coventry, in the design of which the National Physical Laboratory co-operated. These works are devoted to the excessively noisy operation of testing aero engines on the bench. The entire building, which has double walls, and through which a high wind passes, is fitted, so to speak, with an exhaust pipe and silencer, which takes the form of a horizontal brick tunnel 100 feet long, 12 feet high and 10 feet wide, lined with 4 inches of mineral wool and asbestos cloth. This not only serves as an outlet for the wind but reduces the objectionably high noise of the engines to an acceptable figure as heard in the neighbourhood.

Quiet Housing.

Those of us who seek isolation in an endeavour to protect themselves from noise, should first of all choose a naturally quiet site for the building they propose to occupy, and then select a room as remote as possible from such noises as there may be, whether from traffic or other sources. That the sound shadows cast by buildings are sufficiently pronounced to be beneficial finds ample illustration in the quiet gardens of busy cities often
only a stone’s throw from heavy traffic routes. Such screening by inter-
vening buildings is often much more pronounced than the fading with
distance, which latter, on the inverse-square law, is at the rate of 6 phons
for a doubling of the distance.

Not all of us are free, however, to pick and choose our locations and,
in some cases, the noise from both within and without a building is such
that only by the most careful planning can quiet conditions be secured
for a reasonable outlay or indeed at all. For the rest, the remedies depend
on the circumstances, but are much the same as those for the noisy source
viz. double windows and doors and possibly walls; double floors, the
upper one resting on resilient supports; as much discontinuity of
structure as is practicable, and acoustic absorbents on the walls and
ceilings. The success of remedial measures in a building already erected
is likely to be limited.

It has to be recognised that modern building design and materials do
not provide protection from noises, whether from inside or outside, like
the more solid houses of a generation ago. Many people can no longer
escape from the noise of their neighbour’s wireless, gramophone, vacuum
cleaner, bathroom or even his conversation. It is a common complaint
that noises such as banging or tapping can be heard throughout the length
and breadth of large buildings constructed on modern lines.

The noise problem is accentuated in the case of the large blocks of
flats which are being erected in all quarters, and which apparently are
mainly adapted for quiet tenants who are prepared to conform in this
respect to a landlord’s reasonable requirements. But there are those who
contend that in communal housing, the acoustic conditions should be
such that noise is automatically confined within the room in which it is
made, so that a slogan of ‘more cry, little noise’ should represent the
situation. They desire to order their own home life, even if it takes the
form of leaving the wireless on all day and most of the night, the gram-
ophone being there to fill up any gaps. They are opposed to curbing the
natural inclination of their children to play vociferously, bang doors and
run about. On the other hand, they feel that they ought not to be put
in the position of involuntarily annoying their neighbours, even if they
should be invalids, or night workers trying to sleep by day, or who have
children trying to do homework or who go to bed early.

The situation lies largely with local authorities, who should lay down
building bye-laws, setting forth minimum standards of acoustic insula-
tion. The architect and builder have of necessity been driven from
traditional methods of construction to meet the economic requirements
and closer scientific designing of to-day. Discontinuity of structure and
the use of massive and poorly conducting materials formerly provided
defence against sound, but instead we now have monolithic structures
which are not only thinner and lighter than the old, but are composed of
good conducting materials. The steel-framed and ferro-concrete build-
ing, cement mortar, hard bricks and plaster, to say nothing of a general
ramification of central-heating, running water and other piping, have
replaced the softer brickwork, lime mortar and plaster, wooden beams,
joists and studding, and the localised piping of the older houses. No
one pretends, of course, that we can go back to the old methods, but if we are to mitigate the noise nuisance in modern buildings, we must adopt measures which are best incorporated during the designing stage.

There is, too, another aspect which should be clearly appreciated and that is if sound insulation in buildings is desired, it has to be paid for. The public, at present enticed with a plethora of labour-saving devices by landlords of flats, has yet to learn that reasonable acoustic privacy is obtainable provided it is prepared to face a small proportionate increase in the rent.

(i) The insulation of walls and windows.—In the case of walls, par-

![Diagram](image-url)

**Dependence of the sound reduction of single homogeneous partitions upon their weight. (Sound reduction averaged for frequencies 200, 300, 500, 700, 1000, 1600 & 2000 cycles per second)**

Fig. 2.
SECTIONAL ADDRESSES

relation is, of course, impaired by the presence of cracks or badly fitting joints; a surprisingly large amount of sound can be so transmitted.

Measurements show that to increase appreciably the insulating value of a single wall, involves a prohibitive addition to the weight; for example, doubling the weight only adds rather less than 5 decibels to the insulation. The minimum standard of acceptable insulation for a party wall against air-borne sounds is commonly adopted as being that of a plastered 9-inch brick wall (about 55 db). The main escape from the weight relation lies in the use of double or composite partitions free from rigid couplings. Double air-spaced partitions may be divided conveniently into two classes:

(a) Those using light flexible materials in which the mechanical linkage via the edges is small; and

(b) Those using heavy rigid components, in which case linkage via the edges is likely to be substantial.

The first class has been shown by Constable to exhibit resonance effects due to coupling by the air in the interspace, so that the insulating value depends on the spacing and incidentally displays a minimum. The insulation is improved by introducing sound absorbent material in the interspace in such a manner that it does not act as a link between the components. As a practical illustration of these observations, it is recommended for good insulation that double windows should have a sound-absorbent lining at the boundary of the interspace, and that the spacing should exceed a certain minimum, e.g. 4 inches for 21 oz. glass, a properly constructed double window being as sound proof as a 9-inch brick wall. For thicker glass the separation can be reduced. Double windows conforming to these requirements are now commercially available, some of which permit the windows to be opened and still afford an acceptable degree of insulation.

In the case of double partitions constructed from heavy rigid materials, coupling via the edges dominates that due to the air, so that the insulating value can be increased appreciably by framing the components with insulation, e.g. cork strip, round their margins. For example, a cavity partition consisting of two 2-inch clinker slabs separated by a 2-inch air gap and marginally insulated by cork is acoustically as effective as a solid 9-inch brick wall and costs appreciably less, though if the insulation is omitted, the partition is little better than a single wall of the same total weight.

Recent tests show that the insulating value of a single solid wall benefits by the application to both sides of plastered building-board fixed to battens secured by insulating clips. It is of considerable interest to note that the traditional partition of lath and plaster on each side of wooden studding (or a similar partition with fibre board) is definitely superior to a single partition of the same weight. A fire-resisting version consisting of plastered expanded metal on concrete studding affords insulation equal to that of a plastered 9-inch brick wall (of three times the weight).

It should be noted that the insulating value of a wall (or floor) against air-borne sounds originating in a room is often set a limit by the fact
that the sound also falls upon flanking walls (or floors) and is so conducted to other rooms. The effect, which may be appreciated by putting the ear against the flanking surfaces, is likely to be of only minor importance unless the walls or floors have insulating values appreciably greater than that of a 9-inch brick wall.

(ii) The insulation of floors.—The problem is more difficult in the case of floors, for which the important aspect of acoustical insulation is that of reducing the transmission of impact sounds such as footsteps. To measure the insulation of a test floor, it is subjected to blows from a set of mechanically driven hammers designed to simulate heavy footsteps. The noise heard below the floor is measured subjectively by a team of observers. Since no satisfactory method of determining absolute values for insulation against impact sounds has yet been developed, the results are necessarily comparative and show the amount by which the insulation of the test floor exceeds that of some floor of ordinary construction which is accepted as a standard.

It appears that for floors, as for walls, a composite structure is a necessary concomitant of good insulation. Three general methods of providing such a structure have been investigated, viz. :

(a) To lay on the floor a soft material such as carpet on underfelt, or linoleum with a sponge rubber or similar backing;
(b) To lay a ‘floating floor,’ i.e. a supplementary floor supported on insulating material on the structural floor;
(c) To mount an insulated false ceiling below the floor, for example, on insulating hooks.

The first method provides better insulation for sharp blows than for dull blows (such as heavy footsteps), but may be unacceptable on the ground of expense and, in the case of working class dwellings, on account of the unsuitability of the material. The second method is capable of providing good insulation together with a hard upper surface at not too great a cost. So far, two classes of floating floor have been examined, viz. a concrete floor standing upon a number of suitably proportioned rubber blocks; and a wooden “raft” floor resting upon a continuous layer of soft cushioning material such as eel-grass or glass-silk blanket. Both are examples of successful floor treatment, though the underlying factors are not as yet completely investigated. Experiments with the concrete and rubber-block construction have shown that such leakage of sound as occurs from the floating to the structural floor is partly through the rubber supports and partly through the air interspace. A suspended ceiling alone is not usually as effective as the floor treatments, but may be used in combination with them to obtain a greater insulation when necessary, the effects being additive. Neither does a suspended ceiling isolate an impact sound and so prevent transmission to other parts of a building as does a floating floor.

The standard of acceptable insulation for a floor is commonly taken as at least 15 to 20 phons better than that of a bare solid or hollow-tile concrete floor for a test impact which simulates heavy footsteps. It
may be noted that the noise of such impacts heard below a concrete floor is practically as loud as that heard above.

(iii) Sound-absorbent treatment of rooms.—As already mentioned, it is often expedient to subject the surfaces of noisy rooms to treatment with sound-absorbent. This serves a double purpose. It is firstly a necessary adjunct of a sound-insulating wall if it is to operate to advantage, and secondly it serves to reduce the amount of noise built up by repeated reflections at the room surfaces. The extent of the quietening value is, however, limited, as that part of the sound heard directly is not ordinarily affected.

There is a great variety of sound-absorbent materials on the market, ranging from stone and tiles with structural properties to soft flexible materials. Some of the latter are of a fluffy porous nature, so that covers of open texture, or perforated, or even pin-pricked are commonly provided. Some acoustic absorbents have coefficients as high as 90 per cent. and most of them absorb high notes better than low. Meyer has recently developed a non-perforated cover, which may have hygienic advantages, e.g. for hospital purposes. This consists, for example, of thin metal sheets mounted on a wooden framework so that they are spaced an inch or two from a wall to which is attached absorbent material.

Finally, there are two or three other points which may require attention when plans are being made for sound-insulating a building. The first is machinery noise which is liable to be conducted through the structure of a building unless the machinery is properly insulated. For the purpose, it should be mounted upon an undamped elastic support so weighted and proportioned that the frequency of vibration of the machinery on this support is low compared with the frequency of the noise generated.

The second point concerns noise conducted through metal pipes, for example, water pipes. While some of the noise originating in a tap or a circulating pump travels through the water, much of it is directly conducted by the piping itself. It has been found at the National Physical Laboratory that a beneficial reduction (10–15 db) in the noise transmitted along a water pipe can be achieved by replacing a few feet of the pipe with rubber hose.

A third point is the noise of ventilating fans forming part of a system of artificial ventilation which is likely to be an essential accompaniment of a sound-insulated building. Care should be taken that the tip speed of ventilating fans does not greatly exceed 50 feet per second. Ventilating ducts should be lined with sound-absorbent, and a length of canvas hose may advantageously be inserted at some point in a duct.

The foregoing will, I hope, afford a notion of some of the organised steps which are being taken in this country to combat the evil of unnecessary noise. To find practicable solutions to the many ramifications of the problem is, I submit, of material significance to every section of the community.
Chemotherapy may be regarded as the treatment of disease by chemical substances, which have been shown by biological methods to be relatively much more toxic to pathogenic organisms than to human or other animal hosts.

Chemotherapy was developed by Paul Ehrlich, and its most outstanding achievement has been the introduction of the arsenic group of spirocheticides. Very early on, Ehrlich noticed that when certain dye-stuffs were injected into the living animal, they selected certain tissues which were intensely stained, whilst others were left practically free from colour, and as long ago as 1891, he observed that the malarial parasite was strongly stained by methylene blue and thus differentiated from the tissue of the host. It then occurred to him that it might be possible to discover dyestuffs or other drugs whose chemical affinity for disease organisms was so great that the organism might be killed without damage to the tissues of the host.

Successful results were obtained in the laboratory with dyes such as methylene blue, Trypan-red, and Trypan-blue, but the practical value of these dyes has been slight.

In the course of his studies Ehrlich soon found it necessary to find some means of expressing the chemotherapeutic activity of compounds for purposes of comparison. He therefore determined for each new substance the ratio of the minimum curative dose to the maximum tolerated dose, which he called the Chemotherapeutic Index.

The ideal compound would obviously be the one which would destroy the parasitic agents of disease without in any way injuring the cells of the body. Such a compound has yet to be discovered, for every known substance which is toxic to parasites is also toxic to a greater or lesser extent to body tissues. For practical purposes the chemotherapeutic index should be as favourable as possible.

Chemotherapeutic research postulates co-operation between clinicians, biologists and chemists. The first step is the discovery by the biologist in co-operation with the clinician that some parasite is responsible for a given disease. Then methods must be found by which the parasite can be isolated, cultivated and studied. Sometimes this can be done in the test-tube, as in the case of the researches on bactericides and amöbicides,
to which I shall refer in detail later. In other cases, the particular disease, or one closely related to it, may be induced and studied in animals.

Schulemann (1932) has traced the stages in the development of a laboratory method for evaluating antimalarial drugs in the following words: 'In 1880 Laveran discovered the malarial parasite, and in 1891 Grassi and Feletti found in birds a parasite similar to that of human malaria. In 1895, Ross, stimulated and directed by Manson, discovered the rôle played by the mosquito in transmitting the disease. How bird malaria might be used for the study of malarial treatment in man was investigated by Kopanaris and the brothers Sergent, but it was not till 1924 that a satisfactory technique was evolved' by Roehl, who 'worked out a method of using canaries for experiments on lines closely approaching the conditions of practical therapy, so that it was possible to try out and assess in the laboratory many groups of drugs.'

On the chemical side, researches in chemotherapy start from the discovery that some drug, whose constitution is wholly or partly known, is of clinical benefit in a given disease or is toxic to certain organisms. Once some knowledge of the chemical constitution of the drug has been obtained, substances more or less closely related to it can be synthesised and tested for their chemotherapeutic properties.

Traditional knowledge of the value of cinchona bark in malaria, followed by the isolation of quinine and the associated alkaloids, the recognition that the medicinal value of the bark was due to these, and the determination of their chemical constitutions, made possible the chemotherapeutic researches which led to the discovery of plasmoquin and atebrin.

**Bactericides.**

The introduction of phenol or carbolic acid for the prevention of sepsis by Lister in 1867 formed the starting-point in research on bactericides. A very large number of derivatives of phenol have since been made and tested for their bactericidal properties. The effect of substituting one or more alkyl groups in the benzene ring has been studied, and it has long been known that many alkyl-phenols exceed phenol itself in bactericidal value. One method of determining the phenol coefficient of bactericides is the Rideal Walker test, comparing their efficiency with that of phenol in destroying *B. typhosus*. By this test the cresols—methylphenols—have phenol coefficients of 2 to 2.5, whilst thymol—a methylisopropylphenol—has a phenol coefficient of about 25.

In recent years, systematic studies have been made of several homologous series of phenols. An early example of the investigation of a homologous series was made in another field by Morgenroth and his collaborators (1911–1917). They studied the homologous series of alkylhydrocupreines, and showed that peak activity was obtained at the ethyl member (optoquin) for pneumococci, and at isooctyl (vuzin) for *B. diphtheriae*. In clinical use optoquin proved to be unsatisfactory for the treatment of pneumonia, but vuzin was used in the treatment of wounds.

American chemists demonstrated the profound effect of the length of
the side chain upon the bactericidal properties of substituted resorcinols. Johnson and Lane (1921) showed that the phenol coefficients of 4-n-alkylresorcinols rose steadily in the series methyl, ethyl, propyl and butyl, whilst Dohme, Cox and Miller (1926), continuing the series, found a maximum at 4-n-hexylresorcinol, which had a phenol coefficient of 50, the values for n-amyl- and n-heptyl-resorcinol being 33 and 30 respectively. They also showed that the antiseptic value of the n-alkylresorcinols were greater than those of branched chain alkylresorcinols having the same number of carbon atoms.

Coulthard, Marshall and Pyman (1930) studied the variation of phenol coefficient with increase in the n-alkyl-side chain in the 4-n-alkylphenols, 4-n-alkylguaiacols and in four series of n-alkyl-cresols, of which the 4-n-alkyl-m-cresols are the most important. In all cases the maximum effect was shown where the side chain was a n-amyl group. The alkyl-cresols had higher phenol coefficients than alkylphenols containing the same alkyl group, whilst the alkylguaiacols were far less active.

### Phenol Coefficients.

<table>
<thead>
<tr>
<th>p-n-Alkylphenols</th>
<th>4-n-Alkyl-m-cresols</th>
<th>4-n-Alkylguaiacols</th>
</tr>
</thead>
<tbody>
<tr>
<td>R = CH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R = C₂H₅</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>n-C₃H₇</td>
<td>7.5</td>
<td>12.5</td>
</tr>
<tr>
<td>n-C₄H₉</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>n-C₅H₁₁</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>n-C₆H₁₃</td>
<td>104</td>
<td>280</td>
</tr>
<tr>
<td>n-C₇H₁₅</td>
<td>90</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

4-n-Amyl-m-cresol, which had a phenol coefficient of 280 against *B. typhosus*, proved to be highly bactericidal when tested against many other species of bacteria. This is shown in the following table:

<table>
<thead>
<tr>
<th>Test Organism</th>
<th>Concentration lethal in 7½ mins. not in 5 mins.</th>
<th>Ideal Walker</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. coli</em></td>
<td>1-1500</td>
<td>1-80</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>1-2000</td>
<td>1-90</td>
</tr>
<tr>
<td><em>Streptococcus faecalis</em></td>
<td>1-15000</td>
<td>1-75</td>
</tr>
</tbody>
</table>

Pharmacological experiments having shown that it had less than one-half of the toxicity of hexylresorcinol, and that it was non-toxic in medicinal doses, further work was carried out to determine its suitability for use in a mouth wash. In order to test its efficiency in this respect, different dilutions of amyl-m-cresol, compared with plain water as a control, were added to 5 c.c. of a mouth washing. The mixture was
shaken thoroughly, and the bacteria left alive after 5 and 15 minutes were then estimated, with the following results:

<table>
<thead>
<tr>
<th>Tube</th>
<th>Solution added</th>
<th>Colonies after 5 mins.</th>
<th>Colonies after 15 mins.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>5 c.c. water</td>
<td>4,700</td>
<td>5,000</td>
</tr>
<tr>
<td>2.</td>
<td>5 c.c. 1 : 10,000 amyl-(m)-cresol</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>5 c.c. 1 : 20,000</td>
<td>50</td>
<td>4</td>
</tr>
<tr>
<td>4.</td>
<td>5 c.c. 1 : 30,000</td>
<td>1,925</td>
<td>2,169</td>
</tr>
</tbody>
</table>

It was therefore suitable for use as an antiseptic in the oral cavity, and has been successfully introduced into medicine for this purpose.

Clinical trials of 4-\(n\)-amyl-\(m\)-cresol as a urinary antiseptic, however, gave disappointing results, but this is true of phenolic bactericides generally.

Fortunately, a new treatment of urinary infections was introduced by M. L. Rosenheim (1935) two years ago, which is giving excellent results. Previously, urinary infections had been treated successfully by giving patients a particular diet, known as the ketogenic diet, which was very unpleasant to take. It was also known that the principal factor inhibiting the growth of bacteria in the urine of patients receiving this diet was \(\beta\)-hydroxybutyric acid. This acid, however, if given orally would not be effective, because it would be oxidised in the body. Rosenheim, therefore, studied the bactericidal properties of a number of hydroxy-acids and found in mandelic acid a substance which was not oxidised in the body, was non-toxic in therapeutic doses, and was excreted unaltered in the urine, where it exerted its bactericidal effect, the degree of this increasing with increased acidity of the urine.

Specific treatment of streptococcal infections has made much progress since the discovery of the properties of particular aromatic sulphonamides by the I.G. Farbenindustrie A.G., and we are looking forward to an account of investigations in this field from Prof. Dr. H. Hörlein, whom we are very glad to welcome here to-day.

**Amœbicides.**

Research on amœbicides was greatly facilitated by the technique developed by Dobell and Laidlaw (1926), and Laidlaw, Dobell and Bishop (1928) for testing amœbicides in vitro. Emetine (I) has for long been the principal drug used in the treatment of amœbic dysentery, but it has some undesirable by-effects, amongst others a nauseating effect. In a search for substances having the amœbicidal action of emetine without its nauseating effect, a number of alkaloids very closely related to emetine in chemical structure were made at an earlier period. When tested by Dale and Dobell (1917), by an early laboratory method several of them, \(O\)-methylypschodrine (a substance which differs from emetine structurally only in containing two hydrogen atoms fewer) and \(N\)-methylemetine, for instance, were found to be more toxic to *Entamœba histolytica* than emetine itself. Clinical trials of \(O\)-methylypschodrine (Jepps and Meakins, 1917) and \(N\)-methylemetine, however (Low, 1915; Wenyon
and O'Connor, 1917), showed them to be of little or no value in the treatment of amoebic dysentery.

The method of Dobell and Laidlaw, however, depending on the cultivation of amöbae in a medium consisting partly of solid (inspissated fresh horse-serum) and partly of liquid (egg-white diluted with Ringer's fluid) with a little starch, gave results which fell into line with the clinical results. Emetine was found to be fifty times as toxic to amöbae in vitro as N-methylemetine, isoemetine, and O-methylpsychotrine, which are clinically inactive. The clinical inactivity of isoemetine (Low, 1918), a stereoisomeride of emetine, is interesting and reminiscent of the difference between d- and l-stereoisomerides in the cases of adrenaline and hyoscyanine. Later, Laidlaw, Dobell and Bishop described a simpler medium, consisting of 1 part of sterile horse-serum, 8 parts of Ringer's fluid with a small quantity of sterile solid rice-starch, disodium hydrogen phosphate being added as a buffer. In this medium, they found that the amöbae were destroyed in four days by emetine i in 5,000,000, provided that the medium did not become too acid. We have made use of this method in the work which I am about to describe.

In 1927 Brindley and Pyman suggested a constitutional formula for emetine, and in 1929 Child and Pyman synthesised a series of compounds (II) having similar constitutional features in that they contained two 6:7-dimethoxytetrahydroisoquinoline nuclei united through the 1:1' positions by chains of methylene groups.

When tested by Mr. Tate and Miss Vincent, working under Prof. Keilin's direction, at the Molteno Institute at Cambridge, using the
methods employed by Laidlaw, Dobell and Bishop, none of these substances prevented the growth of *Entamoeba histolytica* in culture at a dilution of 1 in 5,000, whereas the control substance, emetine, was effective at a dilution of 1 in 500,000. For the purpose of testing a further series of isoquinoline derivatives, prepared by Child and Pyman (1931), the method of Laidlaw, Dobell and Bishop was used in our own bacteriological department by Mr. Couhhard with the help of strains kindly given to us by Dr. Dobell. This further series was designed to find out whether the reduced benzpyridocoline ring (which is a feature of Brindley and Pyman's formula for emetine), or other systems in which the tertiary nitrogen atom of emetine is common to two rings conferred amœbicidal properties or not. This group of compounds, which included 10:11-dimethoxy-1:2:3:4:6:7-hexahydrobenzpyridocoline (III), proved to be but feebly active compared with emetine, for the most highly amœbicidal member of the series 9:10-dimethoxy-3-phenyl-5:6-dihydrobenzglyoxalocoline (IV) only prevented the growth of *Entamoeba histolytica* in cultures at a dilution of 1 in 25,000, whereas the control substance, emetine, was effective in a dilution of 1 in 500,000.

The fact that we had now suitable strains and a technique for carrying out amœbicidal tests *in vitro* led us to test a series of compounds, originally prepared for another purpose, with interesting results.

This investigation had its origin in Gunn and Marshall's (1920) discovery, that harmine and harmaline had some therapeutic action in malaria. Further clinical trials of these compounds, however, failed to establish their practical worth as antimalarial agents. Since harmine and harmaline are readily accessible in quantity by extraction from *Peganum harmala*, and their chemical constitution has features in common with those of known antimalarial agents such as quinine and plasmoquin, we thought it of interest to prepare a number of derivatives of these alkaloids in order that they might be tested for antimalarial action. Our attention had previously been focused on studies of homologous series in the course of the work on 4-α-amyl-α-cresol to which I referred earlier. This suggested to us that perhaps replacement of the methoxy-group of harmine or harmaline by higher alkyloxy-groups might yield substances of in-

![Chemical Structures](image-url)
creased antimalarial action and the homologous series of normal alkyl-harmols from methylharmol (harmine) up to dodecylharmol was prepared.

Through the courtesy of the Chemotherapy Committee of the Medical Research Council, some members of the series—for example, O-n-butylharmol and O-n-heptylharmol—were tested for activity against bird-malaria under the direction of Prof. Keilin, of the Molteno Institute, Cambridge, but were found to be inactive.

The possibility that some members of these series might have other chemotherapeutic uses was then examined, and it was found that both bactericidal and amoebicidal activity increased, on ascending the homologous series, up to a point and then started to fall. Peaks of bactericidal activity were reached at butyl for B. typhosus and at amyl for S. aureus, whilst the peak of amoebicidal activity was reached at O-n-nonylharmol.

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound</td>
<td>B. typhosus.</td>
</tr>
<tr>
<td>Harmol</td>
<td>1</td>
</tr>
<tr>
<td>Harmine</td>
<td>1</td>
</tr>
<tr>
<td>O-Ethylharmol</td>
<td>25</td>
</tr>
<tr>
<td>O-n-propylharmol</td>
<td>225</td>
</tr>
<tr>
<td>O-n-butylharmol</td>
<td>350–400</td>
</tr>
<tr>
<td>O-n-amylharmol</td>
<td>350–400</td>
</tr>
<tr>
<td>O-n-hexylharmol</td>
<td>50–60</td>
</tr>
<tr>
<td>O-n-heptylharmol</td>
<td>30–40</td>
</tr>
<tr>
<td>O-n-octylharmol</td>
<td>15–25</td>
</tr>
<tr>
<td>O-n-nonylharmol</td>
<td>10–15</td>
</tr>
<tr>
<td>O-n-decylharmol</td>
<td>10–20</td>
</tr>
<tr>
<td>O-n-dodecylharmol</td>
<td>5</td>
</tr>
</tbody>
</table>

The salts of this and other high members of the series were very sparingly soluble in water, and consequently a further series of compounds was prepared, with the hope of obtaining more readily soluble compounds.

The method adopted was to add a further salt-forming group to the molecule in the form of a terminal dialkylamino-group, such as is employed in the antimalarials, plasmoquin (VI) and atebrin (VII).
In this way there were made a series of derivatives of harmol having the general formula (VIII) given below, the salts of which proved, as had been expected, to be readily soluble in water.

![Chemical structure](VIII)

The size of both R (the N-alkyl groups) and x the number of carbon atoms in the chain separating N from O was varied, and the results may be illustrated by reference to a series in which the decyl group (x = 10) was a common factor, whilst the dialkylamino group was varied.

<table>
<thead>
<tr>
<th>Compound.</th>
<th>Minimum concentration lethal to Entamoeba histolytica.</th>
</tr>
</thead>
<tbody>
<tr>
<td>O-α-Dimethylaminodecylharmol</td>
<td>1 in 300,000 to 1 in 500,000</td>
</tr>
<tr>
<td>O-α-Diethylaminodecylharmol</td>
<td>1 in 200,000 to 1 in 500,000</td>
</tr>
<tr>
<td>O-α-Di-n-butylaminodecylharmol</td>
<td>1 in 750,000 to 1 in 2,000,000</td>
</tr>
<tr>
<td>O-α-Di-n-amylaminodecylharmol</td>
<td>1 in 750,000 to 1 in 3,000,000</td>
</tr>
<tr>
<td>O-λ-Di-n-butylaminoundecylharmol</td>
<td>1 in 750,000 to 1 in 4,000,000</td>
</tr>
<tr>
<td>O-n-Nonylharmol</td>
<td>1 in 200,000 to 1 in 500,000</td>
</tr>
<tr>
<td>Emetine hydrochloride</td>
<td>1 in 2,000,000 to 1 in 10,000,000</td>
</tr>
</tbody>
</table>

It was thus found that the activity of members at the peak of the series, such as O-λ-di-n-butylaminoundecylharmol, was many times that of O-n-nonylharmol, and this fact led us to suspect that the harmol residue might not be an important contributor to the amoebicidal properties of the molecule.

A number of compounds were then prepared in which dibutylaminodecyl (or undecyl) groups were introduced into molecules of varying structures. The last columns in the following tables show the limits of the range of the minimum concentration found lethal to *Entamoeba histolytica* in three days, under the conditions laid down by Laidlaw, Dobell and Bishop (*loc. cit.*).
It was thus shown that the attachment of the group \((C_4H_9)_2N.(CH_2)_{10}\) to a simple substituted amino group gave very high efficiency.

A long series of tetraalkyldiamino paraffins of the general formula \(NR'.(CH_2)_n.NRR'\) was then prepared, and the minimum amoebicidal concentration under the optimum conditions for emetine determined.

In the first place, derivatives of heptane and decane were examined; of the heptane series the tetraethylldiamino and tetra-\(n\)-butyldiamino compounds were prepared and tested. The tetrabutyl member of the series was superior as an amoebicide to the tetraethyl one, but neither showed more than a fraction of the efficiency of the best harmol derivative. More promising results were obtained with the corresponding decane derivatives and ultimately the efficiency of dibutylaminoundecylharmol was equalled or even, in some of our tests, surpassed.

The following table shows the results of a test in which a number of decane derivatives of the general formula, \(R_2N.(CH_2)_{10}NR_2\), were examined simultaneously, so that the ‘peak’ of the series could be ascertained. This was found at \(\alpha\alpha\)-tetra-\(n\)-amyldiaminodecane, which was used as a standard of comparison in later work. For brevity, it is referred to below as T.A.D.D.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Minimum concentration lethal to (E.) histolytica.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha\alpha)-Decanes</td>
<td></td>
</tr>
<tr>
<td>Tetra-(n)-propyldiamino</td>
<td>1 in 250,000 not lethal</td>
</tr>
<tr>
<td>Tetra-(n)-butyldiamino</td>
<td>1 in 1,500,000</td>
</tr>
<tr>
<td>Tetra-(n)-amyldiamino</td>
<td>1 in 3,000,000 (or less)</td>
</tr>
<tr>
<td>Tetra-(n)-hexyldiamino</td>
<td>1 in 1,000,000</td>
</tr>
<tr>
<td>Tetra-(n)-heptyldiamino</td>
<td>1 in 250,000 not lethal</td>
</tr>
</tbody>
</table>

A similar test indicated that the corresponding series of undecane derivatives also showed the peak with the tetraamyldiamino member.

Next, keeping a tetrabutyl or tetraamyl group constant, the hydrocarbon residue was varied. The following table shows the results of two tests on these series of compounds.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Minimum concentration lethal to (E.) histolytica.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha\omega)-Tetra-(n)-butyldiamino-</td>
<td></td>
</tr>
<tr>
<td>nonane</td>
<td>1 in 800,000</td>
</tr>
<tr>
<td>decane</td>
<td>1 in 1,000,000</td>
</tr>
<tr>
<td>undecane</td>
<td>1 in 2,000,000</td>
</tr>
<tr>
<td>dodecane</td>
<td>1 in 1,500,000</td>
</tr>
<tr>
<td>tridecane</td>
<td>1 in 1,000,000</td>
</tr>
</tbody>
</table>

**Test 1.**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Minimum concentration lethal to (E.) histolytica.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha\omega)-Tetra-(n)-amyldiamino-</td>
<td></td>
</tr>
<tr>
<td>octane</td>
<td>1 in 400,000</td>
</tr>
<tr>
<td>nonane</td>
<td>1 in 1,000,000</td>
</tr>
<tr>
<td>decane</td>
<td>1 in 2,000,000</td>
</tr>
<tr>
<td>undecane</td>
<td>1 in 1,500,000</td>
</tr>
<tr>
<td>dodecane</td>
<td>1 in 200,000</td>
</tr>
</tbody>
</table>

**Test 2.**
A number of variants on tetraamylidaminodecane were then made in which in the place of the symmetrical tetraamyl group various other combinations were tried, with the results shown in the following table.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Approximate amoebicidal efficiency in comparison with T.A.D.D.</th>
<th>Per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ux-Decanes.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NBu₂</td>
<td>NAm₂¹</td>
<td>100</td>
</tr>
<tr>
<td>NBuAm</td>
<td>NBuAm</td>
<td>100</td>
</tr>
<tr>
<td>NisoAm₂</td>
<td>NisoAm₂</td>
<td>100</td>
</tr>
<tr>
<td>NAm₂</td>
<td>NC₅H₁₀</td>
<td>50</td>
</tr>
<tr>
<td>NMeBz</td>
<td>NMeBz</td>
<td>30</td>
</tr>
<tr>
<td>NETBz</td>
<td>NETBz</td>
<td>25</td>
</tr>
<tr>
<td>NPRBz</td>
<td>NPRBz</td>
<td>20</td>
</tr>
<tr>
<td>NETDodec</td>
<td>NETDodec</td>
<td>10</td>
</tr>
<tr>
<td>NBU Dodec</td>
<td>NBU Dodec</td>
<td>Rather under 10</td>
</tr>
<tr>
<td>NC₅H₁₀</td>
<td>NC₅H₁₀ (Dipiperazino)</td>
<td>Not 10</td>
</tr>
<tr>
<td>NAm₂</td>
<td>NMePh</td>
<td>10</td>
</tr>
<tr>
<td>NHbu</td>
<td>NHBU</td>
<td>Not 10</td>
</tr>
<tr>
<td>NHNon</td>
<td>NHNon</td>
<td>Rather under 10</td>
</tr>
<tr>
<td><strong>Undecanes.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NHAm</td>
<td>NHAm</td>
<td>10</td>
</tr>
<tr>
<td>NAm₂</td>
<td>NH₂</td>
<td>15</td>
</tr>
<tr>
<td>NAm₂</td>
<td>NHbu</td>
<td>100</td>
</tr>
<tr>
<td>NAm₂</td>
<td>NHAm</td>
<td>Over 100</td>
</tr>
<tr>
<td>NAm₂</td>
<td>NHHx</td>
<td>100</td>
</tr>
</tbody>
</table>

A number of compounds were then prepared in order to test the amoebicidal properties of related classes of compounds.

1. Long chain monamines.
2. Quaternary benzylammonium chlorides containing a long chain member, since members of this class have been shown by the I.G. Farbenindustrie A.G. to have marked bactericidal properties, and quaternary salts of the corresponding diamines.
3. Long chain mono- and di-amidines.
4. Compounds in which the 10 aliphatic carbon atoms of decane are replaced in part by 4 carbon atoms of a benzene ring, and in part by 2 atoms of oxygen.

None of these approached tetraamylidaminodecane in amoebicidal efficiency *in vitro*, as will be seen from the individual results given below:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Approximate amoebicidal efficiency in comparison with T.A.D.D.</th>
<th>Per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexadecylamine</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>‘Octon’ (methylamino-6-methyl-2-heptene-2)</td>
<td></td>
<td>Not 10</td>
</tr>
<tr>
<td>Dibutylmethylamine</td>
<td></td>
<td>25</td>
</tr>
</tbody>
</table>

¹ All radicles are of the normal series except where stated otherwise.
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Group 2.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethyldodecylbenzylammonium chloride</td>
<td>10</td>
</tr>
<tr>
<td>Decane-1 : 10-bis (benzyl(dimethylammonium chloride)</td>
<td>Not 10</td>
</tr>
<tr>
<td>Decane-1 : 10-bis (benzyl(dimethylammonium chloride)</td>
<td>30</td>
</tr>
</tbody>
</table>

Group 3.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lauramidine</td>
<td>Not 10</td>
</tr>
<tr>
<td>Sebacamidine</td>
<td>10</td>
</tr>
<tr>
<td>Decane-1 : 10-diamidine</td>
<td>Not 10</td>
</tr>
</tbody>
</table>

Group 4.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p$-$\beta$-Tetrabutyldiamoethoxybenzene</td>
<td>15</td>
</tr>
<tr>
<td>$p$-$\beta$-Tetra-amylldiamoethoxybenzene</td>
<td>33</td>
</tr>
</tbody>
</table>

In considering the results of the foregoing tests, it must be recollected that there is a large margin of error, and in the results given previously we have quoted the minimum concentrations found lethal in a number of tests; in the case of compounds which appeared promising we have usually carried out six or more tests. In our hands, the test of Laidlaw, Dobell and Bishop easily distinguished between compounds in the ‘peak’ area and those at each extremity, but comparison between the members of a series near the peak of efficiency was difficult. This fact may be illustrated well by reference to the table (see p. 69) recording the direct comparison of the amœbicidal properties of tetra-$n$-butyl- and tetra-$n$-amyl-diamoalkanes.

As the result of the foregoing experiments $ax$-tetra-$n$-amylldiamo-$n$-decane (T.A.D.D.) was selected for further study. The conditions of all the amœbicidal tests described above were those most favourable for emetine, that is, in a faintly alkaline medium. It is well known (Laidlaw and others; Henry and Brown, 1923) that the exceedingly high efficiency of emetine in vitro, of the order of 1 in 5,000,000, is only found in alkaline, neutral or only very faintly acid media. Our results afford abundant confirmation of this fact. When endeavouring to assess the value of an amœbicide in the treatment of amœbic dysentery by comparison with emetine in vitro it appears therefore necessary to consider carefully the hydrogen ion concentration likely to be met with in the areas infested with amœbæ.

We have been unable to find any reference to the actual hydrogen ion concentration in the amœbic ulcer, but Knowles and others (1923) found that the pH of a number of stools containing motile amœbæ averaged 6.22. They also reported the results of experiments on kittens artificially infected with $E$. histolytica in which the colon and rectum of the animals were minced in saline and the hydrogen ion concentration of the suspension determined. The average pH value obtained in these experiments was 6.33, and the livers when similarly treated showed an average pH value of 6.34.

Furthermore, a considerable amount of work has been carried out upon the reaction of living, dead and diseased body cells, and the work of Rohde (1927) and Chambers and others (1927) suggests that the contents of the ulcers may have a hydrogen ion concentration more acid than pH 7.0.
A consideration of these papers suggested that in any comparisons of amœbicides with emetine in vitro the effect of acidity should be studied, particularly when the amœbicides are to be administered orally, and that tests should be carried out at a pH value of 6·2 or 6·3.

Under these conditions T.A.D.D. is three to five times as efficient as emetine. Moreover, when blood is added to the medium even at pH values otherwise favouring emetine, T.A.D.D. and emetine are of very similar amœbicidal value, the former at times showing a definite superiority.

The toxicity of T.A.D.D. to mice has been compared with that of emetine with the following results:

<table>
<thead>
<tr>
<th></th>
<th>Oral.</th>
<th>Median Lethal Dose mg./g.</th>
<th>Subcut.</th>
<th>Intraven.</th>
</tr>
</thead>
<tbody>
<tr>
<td>αx-Tetra-n-amyl-diaminodecane dihydrochloride</td>
<td>0·45</td>
<td>0·35</td>
<td>0·04</td>
<td></td>
</tr>
<tr>
<td>Emetine dihydrochloride</td>
<td>0·04</td>
<td>0·06</td>
<td>0·013</td>
<td></td>
</tr>
</tbody>
</table>

It has thus only one-tenth of the toxicity of emetine when administered orally to mice, and one-sixth on subcutaneous injection. Its therapeutic index is therefore much more favourable than that of emetine, and it appeared to be an exceptionally promising compound for clinical trial in conditions of ill-health due to infestation with Entamoeba histolytica. At this point, it was recommended to and accepted by the Therapeutic Trials Committee of the Medical Research Council for clinical trial. It was tried clinically by Prof. Warrington Yorke, F.R.S., who has kindly allowed me to state his results. He finds that T.A.D.D. has some action in amœbic dysentery, when administered orally, but is not sufficiently active to be of any real value. Unfortunately, it cannot be given intramuscularly, subcutaneously or intravenously as it is intensely irritating.

It appears, therefore, that the comparison of the amœbicidal values of emetine and T.A.D.D. with a faintly alkaline medium gives a better indication of their relative clinical value than the comparison in a slightly acid medium. This knowledge will be of value in further work on the subject.

The foregoing account of investigations in chemotherapy indicates the enormous amount of chemical and biological work involved in attempts to evolve new drugs for the treatment of disease. Investigations of this type involve the team-work of a group of chemists and biologists before the selected product reaches the clinicians, and in the present case I should like to pay special tribute to the parts taken in it by Mr. Coulthard on the bacteriological side and Mr. Levene on the chemical side. Only a limited number of private concerns have the facilities for such cooperation, and it is therefore very satisfactory to know that work of this character is being carried out under public auspices, such as the investigations into anti-malarials directed by Prof. Robinson under the Chemotherapy Sub-committee of the Medical Research Council, and those
Dilutions tested against *E. histolytica*, the presence of living amöebae after the test period being indicated by +

<table>
<thead>
<tr>
<th></th>
<th>Test A</th>
<th>Test B</th>
<th>Test C</th>
<th>Test D</th>
<th>Test E</th>
<th>Test F</th>
<th>Test G.²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetra-n-butyl-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>diamino-nonane</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>decane</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>undecane</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>dodecane</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>tridecane</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Tetra-n-amyl-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>diamino-octane</td>
<td></td>
<td>--</td>
<td>--</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>nonane</td>
<td>++</td>
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² No subcultures made.
on arsenicals directed by Sir Gilbert Morgan under the Department of Scientific and Industrial Research.

References.

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Jepps and Meakins: B.M.J., ii, 645 (1917).
Laidlaw, Dobell and Bishop: Parasitology, 20, 207 (1928).
Low: B.M.J., ii, 715 (1915).
Before I turn to the substance of my Address, I feel that I must avail myself of my privilege as a president to wander from my subject, and speak briefly of a matter that is very much in my mind. I refer to the recruiting of the amateur geologist and to the training required to fit him to undertake original research. As a field of activity for the amateur, geology is unique among the sciences; for its laboratory is the countryside, and the equipment required for many sections of the subject is simple and inexpensive.

When we ponder over the wonderful foundations that were laid in all the principal branches by the early workers who were nearly all amateurs, and when we consider the value of research still in progress or recently completed by present-day enthusiasts, such for example as Cobbold, Wickham King, Green or Bisat, it would be a thousand pities were the species to be added to our list of extinct monsters. Yet I think it will be agreed that, whereas the number of professionals is perhaps increasing, there is a dearth of men and women who are at once capable of research and ready to undertake it in their spare time and on their holidays.

First, as to the recruitment of amateurs: some are caught young, others are driven to it, may be, by unemployment; but the underlying reason for taking up the subject is usually found to be the same, namely that the man has been attracted in the first place by the broader interests of the science, such as its explanation of scenery, its interrelation to man's activities, its view of Time, its evidences of how life has proceeded in the past, and its lessons for the future. The fact that geology is a science that can be pursued out-of-doors is also undoubtedly an additional attraction.

Having found our recruit, he has to undergo training before he can be of real value as an observer, recorder and interpreter. The most essential thing is that he should acquire a broad foundation of basic principles. Without this he will never have the vision to see how any specialisation he may later indulge in or any contribution he himself may make, falls into
place as part of the whole edifice of the science. Without this also he may fail to recognise the distinction between the methods and the purpose of research. Yet this breadth of outlook is not easily come by. On the one hand, it involves the acquisition of a certain modicum of first-hand knowledge of minerals, rocks and fossils as entities, and as they occur in the field; on the other hand, it demands wide reading. It is the difficulties of the latter that I wish to stress. At the very beginning the recruit is confronted by half a dozen or more aspects of the science—petrology, palaeontology, tectonics, seismology, and so on—each a regular and complex study of its own, and yet all wanted for the proper understanding of the whole. The textbooks on each subject, in so far as they exist, have generally been designed for the use of the specialist rather than to show the beginner what place that branch occupies within the framework of our science. He is perhaps advised to supplement his textbook by reading recent papers. These he finds are in various languages and scattered through a number of journals that are rarely to be found in any ordinary library. Though it is no doubt salutary for a man at an early stage to go to some of the original sources, there is a limit to the time available; and we must also be sure that he can find the treasure we send him to look for among all the lumber it is hidden away with.

It seems to me that one of the crying needs of the day is for up-to-date books on each aspect of geology. It has been said, I believe, that every textbook is out of date before it is printed. Certainly knowledge is always increasing and interpretation always changing; but surely each of the sections of geology has now been sufficiently explored for the leaders in that particular branch to be able to distinguish and segregate the essentials, so far as we know them, and to present them with a reasoned digest of the evidence as the present-day outlook on the subject. Were this done, one of the greatest of the beginner’s needs would be supplied, for he would have access to the main results so far achieved for that special science. Such books would be a boon not only for the beginners, but for the researchers and specialists in other branches, and I venture to predict for the workers in other sciences, and even for our friend the ‘man-in-the-street.’

The books I have in mind—would not be the so-called ‘popular introductions to geology,’ but small textbooks, each dealing with the attainments of some section of the subject and written in language that should be understandable by any intelligent person who has had a good school education. A natural and very necessary sequel would be attempts to correlate the results of all the branches, and to show how they unite to give an idea of the present state of geology as a whole. These would be general treatises written from various angles, and would therefore demonstrate the multiplicity of the lines of approach, the recognition of which might well induce a man to take an active part in some section who is at present daunted by the magnitude of the whole.

Having unburdened myself of these remarks to which I have been impelled by a haunting fear that with the next generation we may no longer see men devoting themselves to our science for the love of it, I will turn to the main theme of my address, The Pleistocene History of the
West Midlands, a study which owes nearly all its data to the work of amateurs. I will name the most outstanding that all may know our indebtedness to them: Strickland, Lucy, Crosskey, F. W. Martin, Jerome Harrison, Mantle, Codrington, Deeley, Harmer, Gray, Lins dall Richardson, Miss Tomlinson, and many others.

For the purpose in hand I also want to record my appreciation of the work of many professionals, especially members of the Geological Survey, in particular Fox Strangways, Barrow, Gibson, and Cunnington, among the older workers, and Whitehead, Dixon and Dines among the present officers.

A few years ago at the York meeting in 1932, we listened to Prof. Boswell’s wonderful synopsis of our knowledge of East Anglian Drifts, and his attempt at their correlation with others in various parts of the country. He would probably agree with me that perhaps the weakest links in his chain of evidence are those that connect the Midlands with other glaciated areas. Here, the drifts are very denuded and for the most part belong to the Older Series, the area is extensive, and despite a large number of rather disconnected investigations a clear view of the whole is lacking. In my attempt to rectify this deficiency, I have been forced, like my predecessors, to limit the size of the area in which I could acquire a real intimacy with the drifts. I have, however, drawn widely on published accounts of other districts. In addition, I have employed a new line of approach by studying the river deposits as an aid to the dating of the glacial drifts. Since much of the region was, perhaps for the greater part of the Pleistocene, outside the limits of the ice sheets, an understanding of the river development is essential to any interpretation of the history of events.

What Boswell essayed for East Anglian glacials, King and Oakley have attempted for the Thames river deposits. The close correspondence between the movements of sea level suggested for the Thames and those which appear to have taken place in the Somme and the Severn, serves to reinforce the interpretation of the very complex evidence presented by the Thames which these authors have put forward. It encourages me also to feel some confidence in my reading of the Severn evidence. In the sequel I try to show how the river history helps to clear up the story of the glaciation of the Midlands.

At this point I wish to insert a warning. Syntheses, such as Boswell’s, and King and Oakley’s, read so convincingly that beginners and even maturer students accept the conclusions, gladly but uncritically; whereas the authors themselves are very conscious that their heroic attempts at a general theory are little better than a number of working hypotheses put up, like Aunt Sallies, for anyone to shy at. I, at any rate, regard this attempt of mine in that light.

The Different Types of Drift and Their Distribution.

The region I propose to deal with is bounded on the west by the northsouth line of hills from the Clees in Shropshire to Malvern; on the south by the Cotteswold escarpment; and on the east by the watershed
surrounding the headwaters of the Avon (Fig. 1). Its northern limit may be defined by a line from Iron Bridge to Wolverhampton, Lichfield, Tamworth, Nuneaton, Rugby. Within these boundaries there are the two great vales of Severn and Avon embracing on the west, south and east a triangular plateau drained by the Cole, Blythe and Tame which carry its waters away northwards to the Trent. In this 'Midland Plateau' is the high ground of the South Staffordshire Coalfield reaching via the Lickey Hills into East Worcestershire and West Warwickshire, and into the high ground of the East Warwickshire Coalfield: the lower ground of the Cole and Blythe valleys between these heights is itself elevated—an upland rather than a vale.

The greatest anomaly in the topography is the valley of the Severn which is cut, first as a gorge through what should be a major watershed at Iron Bridge, and later as a sort of groove along the west side of the great vale-like depression whose centre-line lies a few miles to the east. It is prob-
able that in pre-Glacial times the upper Severn went to the Irish Sea, that the watershed of England separated it at Iron Bridge from the middle and lower Severn, which then had its source where now the Worfe rises. From here, as indicated diagrammatically on Fig. 1, it may have followed the line of the great depression now occupied by the valleys of the Worfe and Claverley Brook, the Lower Stour, the Elmley Brook and Salwarpe, and the Bow and Piddle Brooks.

In throwing our minds back to this distant period, however, it is essential to remember that a study of the sub-drift surfaces and of the river terraces makes it abundantly clear that the whole river system of the Severn and Avon was then at a considerably higher level than it is to-day, though naturally the differences in level between the present and the pre-Glacial valley-floors decreases almost to the vanishing-point as the watersheds are approached. These relationships do not obtain, at any rate on the same scale, in neighbouring drainage basins, particularly in those draining to the Humber and Wash. The difference in behaviour is in my opinion due primarily to the fact that the Severn and Avon were, all through the Glacial period, principal lines of drainage from the ice front, and in the later stages also received from the Upper Severn water that should have gone to the Dee and Mersey. Thus they carried far more water then than they did in pre-Glacial times and than they do to-day. The overdeepening of their valleys is more the outcome of increased volume than of increased velocity due to elevation. This hypothesis explains the differences between the Severn and the other rivers without having to invoke differential uplift.

A thorough appreciation of the vast extent to which erosion has gone on, and of the enormous length of time involved at once helps us to understand the apparently anomalous distribution of Glacial drifts in this region, in which, as a rule, the vales and lower ground are free from Glacial deposits, whereas the higher country and the watershed areas are extensively and often heavily drift-covered—a disposition that is the exact converse of the usual arrangement in a glaciated region. I shall attempt to show in the sequel that the drifts formerly extended beyond the regions where they now form large outcrops and that their absence from an area need not be taken as an indication that it was never under ice.

It is advisable that at this point a brief statement be made of the geographical distribution of the areas that may be termed drift-covered. In some cases the Glacial deposits are thick and continuous, in others they may be more scattered and are often thinly developed. The term 'drift-covered' is nevertheless appropriate when comparison is made with the rest of the region which can fitly be called 'drift-free,' though here again the description is not literally true. The drift-covered areas may be grouped in relation to the major watersheds, as follows:

1. Watershed between the Tern and Penk on the north and the Severn, Worfe and Smestow on the south, and between the Penk and the Shenstone Brook. This area extends over high ground from the Wrekin towards Wolverhampton, and thence north-east towards Cannock Chase. It also covers lower ground in the Worfe basin.
and at the head of the Smestow Brook. Towards the north-west it is continuous with the heavily drift-covered plain of North Shropshire.

2. Watershed between the Tame on the north and the Penk, Severn and Avon. This contains most of the Midland Plateau, as defined above (p. 74).

3. The watersheds between the Avon, Anker and Soar. This area extends over comparatively low ground from the Leicestershire Coalfield and Charnwood past Market Bosworth and Hinckley to Coventry and Rugby.

![Fig. 2.—The Spheres of Influence of the glaciers that invaded the Midlands:—
1. Little Welsh glacier or 'Welsh Re-advance'; 2. Main Irish Sea glacier; 3. Stratford Stage of, and 4, Supposed maximum of Great Eastern glacier; 5. Maximum of First Welsh glacier; 6. Possible southern limits of a very early Eastern glacier.](image)

Each of these three areas is characterised by a particular type of drift (Fig. 2). Yet each type is by no means confined to one district, but as a rule has had a wider distribution, evidence for which may in some cases be found in the intervening vales (Fig. 3).

In the first or north-westerly district the drifts belong, perhaps exclusively, to the Main Irish Sea glaciation. They are full of Scottish and
Lake District erratics, and contain fragments of shells picked up from the floor of the Irish Sea. In addition, there is material from Wales, but this for the most part has probably been incorporated from the deposits of earlier glaciations. There seems very little evidence of such older deposits still in their original positions, though the Survey record Irish Sea drifts at very different heights within a small area of the Trent valley south and east of Stone, and again on and near Cannock Chase. At Wombourne too, red boulder clay without Irish Sea material and with solifluxion contortions may belong to an older series.

The Irish Sea glacier advanced inland counter to the drainage, and in our district surmounted the watershed and spread a short distance down the valleys of the Severn, Worfe, and Smestow on the south, and entered the valleys draining eastwards to the Tame and even advanced some way down the Main Trent valley (Fig. 2). Its drifts reach to 800 O.D. at Castle Ring on the east side of Cannock Chase.
It is significant that its deposits occur on the watersheds, and at the same time reach into the valleys.

The southern limit of the Main Irish Sea drifts is shown on Fig. 2. It is generally marked by a great concentration of boulders. In some places they are so numerous that all the garden walls in a hamlet may be built of Scottish and Lake District granites. Most of the line between Bridgnorth and Walsall on Fig. 2 is to appear on the forthcoming Dudley sheet of the Geological Survey. I have the Director’s permission and Mr. Whitehead’s consent to publish it. It was traced partly by myself, but chiefly by Mr. Whitehead, to whom I am indebted for much help in this and other matters. The continuation east of Walsall is based on earlier work by the late F. W. Martin, H. G. Mantle and others. As shown by the alternative lines on Fig. 2, there is considerable doubt here as to the exact limits. The same is true in the Trent and Shenstone valleys.

It is now generally accepted that we can divide our British Glacial deposits into ‘Older’ and ‘Newer Drifts.’ The Newer can be recognised by reason of the freshness and unaltered state of their surface features which exhibit clearly original forms like kames, âsars, kettle-moraine, moraine-lakes, and so on. Their obvious influence on, and relation to, the present drainage is another characteristic feature. On both these counts, the Irish Sea Drifts of this north-western area must be regarded as part of the Newer Drifts. Outside the line marking their limits the rest of the Midlands belongs to the realm of the Older series, and has remained extra-glacial since the time of the deposition of the latter. As might be expected under these circumstances, the Irish Sea Drifts have not undergone the extensive denudation to which the rest of the region has been subjected.

It is fortunate that the Irish Sea Glacier brought with it a great influx of Scottish and Lake District erratics, for such vast numbers of them found their way into the Severn via the Worfe and Smestow as to give a characteristic lithology to the Main and Worcester Terraces, by which they can be recognised with certainty as later than the terraces which belong to the time of the ‘Older Drifts.’ In the latter such rocks are conspicuous by their absence.

‘The other two districts belong to the domain of the ‘Older Drifts.’

We may consider next the eastern area. Here the most characteristic drift is the Chalky Boulder Clay and its associated flinty gravels and sands. Though there are other drifts present, these deposits are proved by superposition to be the most recent. As is well known, the Chalky Boulder Clay was the product of a mighty ice sheet to which Harmer gave the title of the Great Eastern Glacier. In addition to chalk and flints, it always contains much Jurassic material which varies with the outcrops over which the ice had passed. The distribution of boulders of Charnwood and Leicestershire igneous rocks and of Jurassic erratics shown on Fig. 3 allows us to trace the trend of its movements.

The limits of the Great Eastern Glacier are indicated on Fig. 2. In the main area, which is that lying east of the Tame and lower Anker, and round Nuneaton, Coventry and Rugby, the drifts are the westward con-
tinuation of the great spreads of Rutland and Northamptonshire so clearly delineated on Harmer's famous map of English Erratics. From the Soar and Anker valleys there is an extension into the Trent valley which is overlapped by the sphere of the Irish Sea glaciation. More evidence is required here before a boundary can be drawn with certainty, but it seems probable that the Eastern ice extended across Needwood Forest. Southwards, the 'Main Eastern' drifts (of Miss Tomlinson) near Stratford-on-Avon appear also to belong to the Chalky Boulder Clay Series. The same is true of the 'Moreton Drift' of the same author, though this can only be linked with those of Stratford by a series of hill-top occurrences in the otherwise drift-free vale of Avon.

In the last of our three drift-covered areas, the Midland Plateau, it is not easy to generalise about the distribution, composition and origin of the drifts. Often they consist of 10-20 feet of pebbly clay, sands and coarse gravel, but there are several districts where far thicker deposits occur. In such cases the drifts may be sometimes sand and gravel, as, for example, at Moxley near Wednesbury, Burtleholm near West Bromwich, Moseley, in the Cole valley, at Rowney Green near Alvechurch, near Barnt Green, at Wildmoor east of B'roughton, and near Kingswinford. At Moxley and Kingswinford the sands lie in channels. At other places boulder clays come in in force, as at the new Hospital Centre at Edgbaston, where there are three boulder clays with intervening sands and bedded silts; California, where the general section is pebbly drift on thick 'indiarubber clays' (probably lake deposits) which in turn overlie coarse sands and gravel and a lower stony boulder clay; Lower Frankley where Crosskey first proved high level (800 O.D.) glacial clay with Welsh erratics; and Blackwell where typical stony till is at least 25 feet thick. Except the California 'indiarubber clay' all these boulder clays appear to be true ground-moraine.

Farther south most of the Warwickshire Plateau has a covering of clayey gravel, sand and sometimes coarse gravel. The high-level drifts of the Ridgeway and of the hill-tops of W'restershire are chiefly sands and gravels, 'fringe' deposits as Jerome Harrison termed them, implying that they were mainly periglacial in origin. On the Ridgeway there are also areas of clayey ground-moraine.

The composition of the drifts varies somewhat, but they always include a great deal of Bunter material, both pebbles from the Middle Bunter and quartz grains from the sandstones. Next perhaps in number are erratics from the coalfields and from the Wrekin area (see Fig. 3). North Welsh rocks are often common, many coming from the Berwyns and the Denbighshire Silurian country. Large boulders of Arenig (and ? Aran) origin are common in the district stretching from Walsall through Birmingham and Harborne, and over the Liceys and Frankley to Bromsgrove. North Welsh material is therefore the most striking of the common far-travelled erratics, and for this reason it is appropriate to term these deposits the Welsh Drifts. To them, however, an Irish Sea Glacier contributed Scottish and Lake District erratics on an exiguous scale. The map
(Fig. 4) gives an indication of where these few wanderers have been met with. We may perhaps infer from their distribution that they belong to a later stage in the glaciation than that which was responsible for the more southerly Welsh Drifts, these being devoid of the Northern elements. It is important to realise that various lines of evidence point to the fact that it was not the Main Irish Sea Glacier, but an earlier one that introduced these few boulders.

Fig. 4.—Distribution of Drifts:—
(1) Welsh Re-advance maximum; (2) Main Irish Sea maximum; (3) Welsh maximum; (4) Older Drifts, Welsh and local; (5) Older Drifts with Pennine boulders; (6) Irish Sea boulders (rare) in older drifts. Those in the Salwarpe valley may be water-borne; those in the Main and Worcester Terraces are omitted; (7) Very ancient boulder clay with north-eastern erratics and overlain by ? Interglacial sands and gravels; (8) Interglacial gravels, 'Jurassic gravels' and 'Ditchford gravels.'

The deposits of the Great Eastern glacier omitted.

Owing to its position between the spheres of influence of the Irish Sea and the Great Eastern glaciers this central area with predominantly Welsh drifts offers borderline cases where it is difficult to decide to which glaciation a particular deposit belongs. The Kingswinford Esker described by Boulton, and the gravels with many northern boulders at
Maney near Sutton Coldfield provide two examples where it is a question of distinguishing between a Main Irish Sea and a Welsh origin; whereas the drifts of the Ridgeway in East Worcestershire seem to be compounded of Welsh and Eastern elements. This long ridge, ranging in height from 550 O.D. in the north to 350 O.D. in the south, bounds the Arrow valley on the west. It is capped for a distance of 11 or 12 miles from near Blackwell to 3 miles south-west of Alcester by a narrow outcrop of sands, gravels and boulder clays. In its northern part a few Irish Sea erratics occur in the clay, but farther south there have been found at Crabbs Cross an Oxford Clay ammonite (Gulielmiceras); and at Weethley flints and a Leicestershire granophyre, all indicating that some of its material came from the north-east. As the Ridgeway lies outside the region of those well-developed Eastern drifts, whose distribution in the Avon valley has been described by Dr. Tomlinson in 1935, two explanations appear possible. Either its eastern elements are relics of a very early Eastern glaciation or they provide a record of a temporary advance of the Main Eastern glacier down the Avon, perhaps as far as Tewkesbury, during which a side-lobe was thrust up the Arrow valley. Other evidence in favour of this latter view is the presence of flint-bearing deposits resembling boulder clay at Harvington (Tomlinson), at Evesham (Dines), at Besford, and on top of the Bushley Green Terrace deposits at Bushley and Apperley near Tewkesbury. For these reasons I have on Fig. 2 adopted the latter explanation, though I realise the slender nature of the evidence.

Over much of that part of the Warwickshire-Staffordshire Plateau which is drained by the upper waters of the Tame, Cole and Blythe, the mantle of drift is comparatively intact, and frequently forms the valley floors; but on the Severn-Avon side of the watershed of England it becomes very ragged, projecting outwards as promontories or forming outliers on the highest hills (Figs. 1 and 4). As we go towards the Severn and Avon these outliers become less frequent and usually smaller, and in some cases a mere skin of pebbles is all that remains. Doubtless the large isolated boulders sometimes met with in otherwise drift-free areas, represent the final fate of such high level drifts.

That the highest points are surmounted by drift is so far a rule that one is forced to view the capping as remnants of a more or less continuous sheet which once stretched far into the vales of Severn and Avon. Here it has in most places been completely destroyed. Evidence of its presence must be sought for on the hill-tops and not in the valleys, all of which in their present state are younger than the glaciation. This statement perhaps needs qualification, for fluvio-glacial deposits occur at fairly low levels near the Piddle Brook and in the Salwarpe and Stour valleys. These, however, appear to belong to the waning phases of the glaciers when the lower parts of the vales, freed from ice, had become subjected to river erosion. The new valley floors thus formed then received deposits from the glaciers which still occupied the country further north.

It is, I think, fair to conclude that the ice sheets at their maxima occupied the vales, and that these were far shallower then than now. This
hypothesis sounds very speculative, but there are some remarkable pieces of evidence in its favour.

1. Near Gloucester and adjacent to the rivers Severn and Leadon, coarse gravels, probably fluvio-glacial in origin, cap hills at about 200–280 O.D., the present valley floor being about 25 O.D.

2. Three drift-capped hills, Dripshill (ca. 240 O.D.) between Worcester and Upton, and Leopards Grange (320 O.D.) and Crookbarrow (280 O.D.), both near Worcester, are all quite close to the river which floods at about 40 O.D. Sands occur at 200 O.D. near Peachley north-west of Worcester. In the Salwarpe basin near Elmbridge boulder clay caps the hill at 231 O.D. This is in the pre-Glacial depression referred to above as lying east of the present Severn valley.

3. In the Avon vale supposed Welsh drift occurs at Wolford (ca. 350 O.D.), and at the Campden Tunnel (520 O.D.), both near Moreton-in-the-Marsh. In the same district, as already mentioned, the Moreton Chalky drifts lie at a level of 449 O.D. and actually form the water-shed between the Thames and Avon. All these occurrences are on the south side of the vale, and are only connected with the South Warwickshire Plateau by a few hill-top outliers, such as Idlecote Hill (435 O.D.), Long Hill near Loxley at 415 O.D., and the hill-tops at 415 and 446 O.D. near Eatington. Welcombe Hill (350 O.D.) and Cracombe Hill (377 O.D.), both capped by thick drift, are close to the Avon, which is about 125 O.D. and 70 O.D. in their respective neighbourhoods.

These facts tend to show that at the time of the glaciation the valley floor was much higher than now.

4. On the south-west slopes of the Clent-Lickey range, there are at Money Lane, Wildmoor, sixty feet of horizontally bedded sands capped by thirty feet of horizontal coarse bouldery gravels which reach to about 730 O.D., the whole banked against a steep slope of Bunter. Similar confirmatory sections can be seen near-by and also at Combe Hill, Barnt Green. It seems impossible for such horizontally bedded sands to have originated except in a lake, and equally impossible for a lake to be held up in this position except by means of a large glacier in the lower ground to the west. Out in this direction there are a number of hills near Bromsgrove, Chaddesley and Bembrough, the drift capping on which proves that they, too, were once under the ice sheet. Here it varies in height from 350 to 519 O.D.

5. The great sand mounds of the Stour valley and the sands and gravels at high levels near Churchill seem to demand a large lobe of ice to account for their presence there; and the composition of these drifts, which are practically free from northern erratics, makes it clear that they are unconnected with the Main Irish Sea glaciation.

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1 The 'Campden Tunnel Drift' as now exposed above the Tunnel contains north-eastern elements.
6. The presence of a great lobe of ice down the Stour and down the depression (referred to above), east of the present Severn gorge, could supply a reason for the anomalous way in which the River Severn selects the high Palaeozoic ground in preference to the wide Triassic depression; for the river might have taken this course when it consisted of the marginal drainage off the west side of the glacier. As such it might have cut a large marginal channel which on account of its depth was permanently retained in later times.

THE RIVER TERRACES AS EVIDENCE OF THE STAGES IN THE EROSION.

If we are right in claiming a former far wider distribution of the drifts than the areas where they now occur in force, the river valleys should provide a great deal of evidence concerning the way in which their destruction has been brought about. In the present case this is certainly so; for we have in the Severn and its tributaries a wonderfully developed system of river terraces and of deposits that originated under the rigorous conditions of glacial climates, the so-called tale gravel and melt-water flood gravels. A study of these has thrown much light on our problem.

The farther we go from the plateau and from the drift-covered ground on its north-west and eastern sides the greater the number of high level terraces. In some cases the geographical distribution and the lithological composition enable us to relate a terrace to a particular set of glacial deposits.

<table>
<thead>
<tr>
<th>Severn</th>
<th>Avon</th>
<th>Height at mouth of Severn</th>
<th>Upstream limit Severn</th>
<th>Upstream limit Avon</th>
<th>Composition</th>
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</thead>
<tbody>
<tr>
<td>Bushley Green Kidderminster</td>
<td>No. 5</td>
<td>110/75 O.D.</td>
<td>Tewkesbury</td>
<td>Stratford</td>
<td>Do.</td>
</tr>
<tr>
<td>Main</td>
<td>Nos. 2 &amp; ?</td>
<td>65/35 O.D.</td>
<td>Bewdley (goes up Stour)</td>
<td>Stoneleigh near Kenilworth Church</td>
<td>Do. and S</td>
</tr>
</tbody>
</table>

2 Miss Tomlinson's nomenclature.
3 Height of top/height of base.
4 B, Bunter Pebbles; W, Welsh; F, Flints; M, Malverian; S, Scottish and Lake District.
The table illustrates this (see also Fig. 5) and makes it clear that: (1) the highest or Woolridge Terrace is only recognizable below Tewkesbury. (2) The next or Bushley Green Terrace goes up the Avon as Avon No. 5 to Stratford, and ends just where the Main Eastern glacials begin to appear in force. (3) The next, the Kidderminster Terrace or Avon No. 4, is met with throughout the area, but it leaves the Severn to go up the Stour and not up the Bridgnorth and Iron Bridge gorges; (4) the Main (Avon No. 2) is met with in the Avon throughout our area, and in the Severn it reaches to the Iron Bridge gorge and into the Worfe valley. Here, as already pointed out, it clearly ties on to Irish Sea glacial deposits. It is also recognised in all the tributaries, and by its distribution and relation to the taele gravels, reinforces the arguments that have already been used to show that the north-western section of the region was the only part under ice during the time of the Newer Drifts. (5) The Worcester Terrace is poorly developed up the Avon, but extends up the Severn from near Tewkesbury through the Iron Bridge gorge to Shrewsbury where it appears to link on with the Welsh Re-advance. Its distribution shows that the Iron Bridge gorge was then functioning, but at a height of about sixty feet above the present level.

I have elsewhere discussed the extremely ambiguous evidence bearing on the question whether there was an interglacial episode between the time of the Main and Worcester Terraces, without being able to obtain an assured answer. On the other hand, the fauna of Avon No. 4 is a warm climate one, which makes it probable that both it and its correlative, the Kidderminster Terrace, are interglacial. The position of Avon No. 4 Terrace below Avon No. 5 which connects with the Great Eastern glaciation, and above the terraces, Avon No. 2 and ? No. 3, which correlate with the Main Terrace of the Severn and so with the Irish Sea glaciation, forces us to conclude that these two glaciations were not contemporaneous.

Various lines of evidence converge therefore towards the following conclusion: that the Bushley Green-Avon No. 5 Terrace and the still higher Woolridge Terrace are to be correlated with the 'Older Drifts'; that the Main, the Worcester, and Avon No. 2, and possibly Avon No. 3, Terraces, belong to the 'Newer Drifts'; and that the Kidderminster-Avon No. 4 Terrace records the intervening 'Great Interglacial.' The question whether the older drifts of the Midlands bridge more than one glacial epoch is dealt with in the sequel.

**The Older Drifts.**

The most outstanding problem is that of the Older Drifts. It may be a long time before a correct solution of this is achieved. At the moment I can offer only a brief synthesis of the results obtained by other workers compounded with ideas that I have accumulated during my study of the drifts of the Western Midlands. Those of the Eastern Midlands I scarcely know; but luckily some parts of that area have been carefully described by the Geological Survey (in particular by Fox Strangways, Gibson and Barrow), and there are illuminating accounts of
some other parts by Deeley, Wilson, Beeby Thompson, Jerome Harrison and Shotton.

The 'Older Drifts,' as already pointed out, are essentially either north-western (or Welsh) or north-eastern in composition. We may now examine them to determine whether they record more than one glacial epoch. For this purpose we can divide the region into two parts along a line running roughly from Derby—Lichfield—Tamworth—Coventry—Stratford-on-Avon to Moreton-in-the-Marsh.

East of this line two distinct sets of glacial deposits can be recognised on lithological and stratigraphical grounds. The older of the two, as developed in the north, is of Pennine origin, and was carried by ice travelling from the north-west (Figs. 4, 5, and 3); but near Coventry and Rugby drift occupying an analogous position contains chalk and flints, and can be described as a sort of chalky boulder clay. Its apparent southerly limit is shown in Figs. 4, 7 and 2, 6. In the intermediate district little is known, but near Hinckley and perhaps also at Bedworth part of the older series consists of well-bedded, probably lacustrine deposits. The drifts on the Blythe-Avon watershed near Stratford-on-Avon, and the 'Campden Tunnel Drift' near Moreton appear to be Welsh in origin. They have both been regarded as probably older than the Great Eastern glacier (Tomlinson).

Throughout all this eastern region the upper or more recent drift has been derived from the north-east and often consists of a true chalky boulder clay. It has generally and, I think, correctly been referred to the Great Eastern glaciation of Harmer.

If we examine the map (Fig. 3) showing the distribution of glacial striae and of boulders of Midland origin in this eastern region, we note that the Pennine group travelled towards the south-east, whereas there is a great stream of Leicestershire rocks towards the south and south-west. These two directions are certainly an index of the movements of the older and more recent glaciers respectively.

Between the lower and the upper boulder clays in the Hinckley-Coventry-Rugby district there is a persistent bed of gravel and sand. Somewhat similar deposits, the Jurassic gravels of Miss Tomlinson, underlie the 'Main Eastern' boulder clay of the Stratford area. The 'Ditchford' or 'Paxton' gravels of the Moreton district occupy an analogous position with respect to the chalky 'Moreton Drift' (Tomlinson and Dines). See Fig. 4, 8. In the Jurassic gravels near Stratford, a single tooth of an archaic form of Elephas antiquus has been found, which is suggestive of interglacial conditions. Near Coventry both cold and warm climate fossils have been recorded by Shotton. In view of the close association of these deposits with two glacial series, the presence in them of tundra and temperate fossils is not so contradictory as would at first sight appear, especially as we must allow that vast lengths of time may be represented by comparatively thin deposits in a watershed-area, like this, where the levels of the valley floors were not much altered either by erosion or deposition.

See, however, note on p. 82.
I consider that the facts in this eastern region support the idea of two distinct glaciations within the Older Drifts with interglacial conditions between them (First Interglacial). The question of how the lower, very ancient chalky boulder clays of Coventry and Rugby reached that district remains to be solved.

West of the Derby-Moreton line the area of the Older Drifts is sharply limited on the north by the southern edge of the later Main Irish Sea glacials (Fig. 4), which has already been discussed. Except in the Lower Avon valley, the older drifts are here Welsh. The directions of ice-flow are shown on Fig. 3.

The interpretation of these drifts is extremely difficult, partly because it is likely that if there have been two glaciations, they will be recorded by similar deposits which might occur each separately or both together on the same surface, and partly because of the great dissection and destruction that they have undergone. Many of the deposits, too, are gravels and sands that belonged rather to outwash fans than to the ice sheet itself. On the other hand, we have, as already pointed out, the river terraces to help us, by providing a record of the progressive deepening of the valleys and of the contemporaneous opening up and development of new lines of drainage on surfaces, each of which appear to grade with one or other of the terraces, and which for this reason may be regarded as of approximately the same age as the terrace in question.

One is bound to confess that any conclusions that can at present be drawn are very tentative. For this reason I hesitated about setting them out in black and white as diagram maps; but I have decided to do so in order to make clear my present views. It is most essential, however, that the speculative nature of the maps (Figs. 3 and 5) be continually kept in mind. They attempt to express, diagrammatically, the general distribution of the ice and of the main drainage lines at successive stages in the melting of the glaciers, which I think can be deduced from the distribution of the drifts, from their composition, and from their relation to the terrace history of the Severn and Avon.

We may consider the Lower Avon and Lower Severn vales first. Here the highest deposit, namely the Woolridge Terrace, is developed between Tewkesbury and Gloucester, and up the Leadon valley at heights between 200 and 285 O.D. I have elsewhere suggested that the Leadon valley deposits were laid down by water travelling west of the Malvern range and forced to take this course by the filling of the Severn vale by the Welsh ice, when at its maximum (Fig. 3, 1). At this stage, too, the ice seems to have carried Welsh boulders to the Moreton-in-the-Marsh district and to have been responsible for certain very high level drifts in Worcestershire. For these reasons I picture it as stretching over the vales of Severn and Avon to the Cotteswold escarpment. A slight retreat (Fig. 3, 2) would have allowed outwash material to be laid down below Tewkesbury. Patches of this have survived at Woolridge (260 O.D.), Norton Hill (283 O.D.), and Corse Hill (250 O.D.). These and some other very high deposits such as those already referred to (p. 82) at Dripshill (240 O.D.), and Leopards Grange (320 O.D.), and at Cracombe
Hill (350–400 O.D.) and perhaps those on the Avon-Blythe watershed and in the Warwickshire Coalfield and those capping isolated high hills in the Avon vale, seem to belong to this early stage and to be the most likely equivalents of the lower boulder clays of the Upper Avon valley and of the Pennine drifts of the Trent, Soar, and Wreak valleys (Fig. 4, 5 and 7).

If we accept this view, it follows that the retreat of this First Welsh Glacier was connected with the ‘first interglacial’ episode for which we have discussed the evidence in the Upper Avon valley. In the Lower Severn vale the Bushley Green Terrace, containing a temperate shell fauna and lying at a considerably lower level than the Woolridge Terrace, appears to belong to this time. The Bushley Green correlates with the Avon No. 5 Terrace of Miss Tomlinson, but for the following reasons I picture the latter as somewhat later in date though graded to about the same level: the Bushley Green Terrace deposits seem to be overlaid by eastern boulder clay, whereas Avon No. 5 near Evesham lies in a valley cut through eastern drifts, and is also clearly newer than the Ridgeway deposits in which there are eastern elements. I have already given reasons (p. 81) for believing that the eastern drifts referred to were laid down during a rather brief advance of the eastern ice to near Tewkesbury (Fig. 2), and that a more considerable halt was made near Stratford— as described by Miss Tomlinson. On this view the Bushley Green and Avon No. 5 Terraces cover the ‘first interglacial’ episode and the oncoming and maximum stage of the Great Eastern glacier in the Avon vale.

What then of the rest of the region? There are certain data and several lines of reasoning which in my opinion justify us in postulating the existence during the Great Eastern Glaciation of a Welsh ice sheet reaching across the Stour and Salwarpe valleys, and covering the Black Country, East Worcestershire and the Warwickshire Plateau (Fig. 5). There is, however, no clear-cut evidence to prove whether it was the shrunken First Welsh or, as I think more likely, a Second Welsh ice-sheet which, as the first interglacial epoch passed away, grew and invaded the northern part of the same region, incorporating to some extent in its deposits the drifts of the earlier advance.

I will refer very briefly to some of the reasons for my view. First, in the region in question there are, as I have already mentioned, a certain number (perhaps 40 or 50 are known) of small Irish Sea erratics, in the form of Scotch and Lake District rocks, whereas none are known in the deposits already allocated to the First Welsh glaciation. Their distribution is shown on Fig. 4.

Secondly, the deposits in some cases occupy valleys that seem to have been excavated below the levels of the oldest drift-sheet. For example, Miss Tomlinson has described evidence for what she refers to as a ‘Welsh re-advance,’ which brought a north-western ice-sheet into the Blythe valley after the deposition of the drifts of its southern watershed, and at the time of the Stratford stage of the Great Eastern glacier.

6 The Packwood and Rowington granite boulders are on the extreme limit of the Second Welsh Sheet as shown on Fig. 4.
Thirdly, there is no obvious connection between the present topography and the First Welsh drifts, but in the case of the supposed Second Welsh drifts, it is possible to see cases where the present drainage seems to have been influenced by the glaciation, as for example the course of the Blythe, as described by Miss Tomlinson. Again, in the Cole valley sands and gravels referable to the Second Welsh glaciation prevent the Cole reaching the Tame near Birmingham and send it six miles to the east before it effects a confluence; and in the Stour valley, as Mr. Whitehead has pointed out to me, the present course through the Bells Mill Gap in the Bunter Pebble Bed escarpment near Stourbridge can be explained by assuming an ice-dam across the original Stour valley at Hinksford.

Finally, outwash material grades down into the valleys at levels which accord with terraces that are far younger than the Woolridge Terrace and therefore far younger than the First Welsh glaciation. One important spread runs east of the Severn from near Stoulton southwards through Wadborough and Besford to grade with Avon No. 5 Terrace, and therefore perhaps to be regarded as comparable in date with the Great Eastern glaciation. Others follow the Salwarpe and Stour valleys, and are but little above the level of the Kidderminster Terrace which itself correlates approximately with the Second Interglacial epoch.

Having stated some of the evidence for a Second Welsh ice-sheet in the Midlands contemporary with the Great Eastern glacier when the latter spread from the north-east into the Eastern Midlands and Avon vale, I can only briefly refer to its retreat. This is illustrated diagrammatically on Fig. 5.

The first position shown is indicated by a line with double offsets. This line conforms with Miss Tomlinson's maximum 're-advance' in the Blythe valley; with the considerable development on the Ridgeway of drifts with both north-eastern and north-western erratics which may have owed their origin to the combined efforts of the two glaciers; and with the gravels and sands of the Stoulton-Besford area which I have just referred to as grading to the same level as Avon No. 5 Terrace. As the two sheets withdrew, the drainage down the Avon was responsible for the formation of some parts of the same terrace. It appears necessary to imagine the Severn valley from Worcester downwards as having already been established, possibly as a marginal flow along the edge of the First Welsh Glacier.

The second stage deserves more elaboration; but this cannot yet be achieved, owing to want of data. The line indicated with three offsets must therefore be regarded as a composite representation of several that it would be necessary to draw in order to satisfy even the evidence we now possess. East of Birmingham the line represents a lobe in the Tame basin connecting near Tamworth with the Eastern ice of the Anker and Trent valleys. This disposition of the two sheets would enable us to account for the Blythe valley lake suggested in the Birmingham Memoir and described by Miss Tomlinson. It drained southwards by the Kings-
wood Gap to the Alne valley during the Stratford stage of the Great Eastern Glacier (Tomlinson).

Ice approximately in the position shown for this stage could also account for the Cole valley lake, the Moseley gravels, and the barrier of sands which turn the river eastwards near Castle Bromwich. Fig. 5 also
indicates a lake in the upper Rea valley, south-west of Birmingham. This expresses the hypothesis that certain clays, such as the ‘india-rubber clay’ of California and the similar deposits at Parson’s Hill, King’s Norton, may have originated as lake clays when the Rea valley was obstructed by ice that impounded water up to about 550 O.D.

The line further coincides to the south-west of Birmingham with the gravel deposits of Rowney Green near Alvechurch which may be regarded as marginal in origin. The lobe stretching southwards complies with the necessity for an extension into the lowlands of an ice-sheet that was mighty enough to overspread the high ground of the Black Country and the Lickey Hills. Drainage from this was carried away along the Salwarpe into the Severn, and was responsible for part of the erosion of these valleys before the Kidderminster Terrace came to be formed. It will be noted that the overflow from the Blythe lake coupled with drainage from the retreating Eastern glacier produced similar erosion-effects in the Avon valley before Avon No. 4 Terrace was laid down.

Returning to the melting glacier, the next event seems to have been the splitting of the ice on the high ground of the Black Country. The lobe on the east may have been concerned with initiation of the peculiar drainage of the Shenstone valley which is being investigated both by Mr. Wilfred Bullows and by Mr. S. J. Martin (Fig. 5, line with four offsets). The lobe on the west I picture as occupying the low ground west of the coalfield and of the Clent-Lickey range as far south as the Salwarpe valley. It was this ice that held up the lake or lakes near Wildmoor and Barnt Green which have left their record in the horizontally bedded high-level sands and gravels of that district.

As the ice shrank back the thick mounds of sand and gravel in the Stour vale and near the Churchill brook were deposited. These clearly antedate the Kidderminster Terrace and so fall into their correct position in the scheme.

The final stage, indicated on Fig. 5 by a line with five offsets, was suggested to me by Mr. T. H. Whitehead. There is much evidence to justify the assumption that in pre-Glacial times the Stour flowed northwards as far as Hinksey, where it rounded the end of the then-unbroken Bunter Pebble Bed escarpment. Ice in the position shown on the map would, as already suggested (p. 88), have impounded a lake in the upper Stour valley, the overflow from which might have initiated the present gorge of the Stour through the Bells Mill Gap. The sands of the so-called Kingswinford Esker can be regarded as having originated in this lake.

I am very grateful to Mr. Whitehead for allowing me to use this idea which he is setting out in the forthcoming memoir on the Dudley district; though I am far from confident that he will agree with the date to which I assign the event.

All the records of the further retreat of the Welsh ice sheet have been obliterated by the invasion of the later Main Irish Sea glacier.

The evidence relating to the Older Drifts that we have been considering is scattered, difficult to interpret and usually ambiguous; but nevertheless I feel some confidence in the correctness of the main features of its inter-
pretation, namely that there were two glaciations involved. In the first
the ice movement was from North Wales and the Pennines towards the
south-east: in the second there was a similar, but less powerful North-
Welsh dispersion with some slight intermingling of Irish Sea material.
Simultaneous with this, however, in the east and in the Avon valley was
the Great Eastern glacier.

By the end of the First Glacial epoch the general trend of the lowest
parts of the Severn seem to have been established as marginal channels
bordering the ice which lay thickest in the Salwarpe-Piddle Brook de-
pression. The first and the second glaciations were probably separated
by truly interglacial conditions (First Interglacial).

The Second Glaciation came to an end in the Second or Great Inter-
glacial epoch which intervened between the deposition of the Older and
Newer Drifts. In the area under review we find at this stage that the
present directions of the rivers had been determined, and that the valleys
of those days can be recognised and their depths defined by the Kidder-
minster-Avon No. 4 Terrace, and perhaps by the 'High Terrace' with
Hippopotamus in the Trent valley. There is, however, one exception to
this statement. I refer to the Iron Bridge gorge. This section of the
present river was non-existent at this time, and in its place was a high
watershed. The diversion of the Upper Severn across this waterparting
belongs to the story of the Newer Drifts.

Newer Drifts.

(a) The Main Irish Sea Glaciation.

This address has already become so long that I can only refer in the very
briefest way to the events that have occurred since the 'Great Interglacial.'
I have already mentioned that the Newer Drifts in the Midlands were the
product of the Main Irish Sea Glacier, and I have attempted to define
its maximum extent on Fig. 2. This glacier belonged to the Third
Glaciation.

The oncoming of this glacier seems to have coincided with the deepening
of the Severn valley below the Kidderminster Terrace level, in preparation,
as it were, for the great floods of sand and gravel that were fed into it as
soon as the ice crossed the old watershed near Iron Bridge and at the head
of the Worfe and Smestow valleys. These deposits are now the Main
Terrace, correlatives of which are the Second Terrace of the Avon and
probably the low terraces of the Trent and Tame.

As the ice had been moving upstream in its invasion of the Dee and
Mersey basins, it must have impounded the drainage during the advance,
as we know it did later during the retreat; but there seems to be no record
of an overflow into the Severn catchment during this growth stage. Per-
haps an overflow into the Trent may have existed during the advance;
but the whole story of the effect of this glaciation on the east-flowing
drainage is at present very obscure, in fact, an interesting problem awaiting
investigation.

As the ice melted back from the maximum position shown on Fig. 6, a
series of important drainage changes took place. First, at an early stage
when the ice still covered the watershed at Iron Bridge and at the head of the Worfe, but had melted back enough to expose the upper Penk valley, a small lake was impounded just north of Wolverhampton which flowed out south-westwards over the watershed near Tettenhall, forming the Tettenhall Gap. This overflow was responsible for the great train of gravels full of Irish Sea erratics that follows the Smestow Brook down into the Stour.

Dixon has traced various ice fronts trending in a general north-easterly direction across the country between the Penk and Newport, Salop. These are marked by terminal kames and by beaded āsar.

![Map of the area](image)

**Fig. 6.—The retreat phenomena of the Main Irish Sea Glacier.**

The Worfe valley was an important line of drainage from the ice front until the latter came to lie on the north side of the watershed. In this position a lake was impounded near Newport, and Dixon has shown that this drained across the watershed at Gnosall into the Church Eaton brook and so into the Trent. He named it Lake Newport.

I have elsewhere described the detailed evidence relating to the way in which the waters of the Upper Severn came to be diverted through the Iron Bridge gorge into the drainage basin of the present Middle and Lower Severn. This diversion was brought about during the melting back of the Main Irish Sea glacier on the watershed region near the Wrekin, through the development of a system of marginal channels and glacial lakes. The detailed evidence substantiates a hypothesis suggested
independently by both Lapworth and Harmer, the main feature of which was that a lake was held up by the ice sheet on the north-west side of the pre-Glacial watershed at Iron Bridge; and that this lake drained away across the divide, and thus initiated a gorge that became so deep that it has permanently retained the Upper Severn drainage which formerly went out to sea either by the Dee or by the Mersey. This lake I named Lake Buildwas (Fig. 6).

At this stage then there were two lakes, Buildwas and Newport, on the north-west side of the watershed, one draining to the Trent and one to the Middle Severn. They were separated by the ice where it impinged on the Wrekin. When the glacier melted back further and allowed the lakes to join and form 'Lake Lapworth,' so nearly at the same level were the outlets, that it was a mere matter of chance that the Upper Severn went permanently to the Bristol Channel and not to the Humber. As it happened, the Iron Bridge outlet was, or at any rate soon became, the lower. It took all the discharge and has retained it ever since. This implies that when the ice left Cheshire, the drifts of the Cheshire plain formed across the old pre-Glacial valley a barrier that was higher than the Iron Bridge outlet at the time. It seems likely, therefore, that Lake Lapworth had by then been lowered considerably by the partial destruction of the rock sill at Iron Bridge.

These glacial accidents have been the factors that have determined much of the geography of the Midlands; for they diverted into the relatively small pre-Glacial catchment basin of the Lower and Middle Severn great volumes of water which have rejuvenated the river, especially in its middle reaches, on a stupendous scale. The rejuvenation is still operative and can be seen to-day in the erosive activity of every tributary of the Middle Severn. The relationship of the Main Terrace and its correlatives in the Avon and Trent to the present valley-floor also displays in a striking way the influence of the increased erosive activity on the shape of the valley. The low terraces of the Tame and Trent system which has had no rejuvenation of this type, rise a few feet above the alluvium and extend downwards below the valley floor; the surface of the Second Terrace in the Avon keeps parallel to the present flood plain, but some 20–30 feet above it. Here the rejuvenation has been slightly felt. On the other hand, in the Severn valley the present floor lies 20–30 feet below the Main Terrace at Tewkesbury, but 100 feet below it at Bridgnorth. In fact, from Worcester upstream the Severn is increasingly incised, and its tributaries, the Salwarpe, the Stour and the Worfe, join it in deep trenches.

Climatic conditions during the Main Irish Sea glaciation were extremely severe. Solifluxion and melt-water floods were on a correspondingly grand scale in the periglacial region. There are vast spreads of local, often angular, detritus at the foot of the Cotteswold and Malvern Hills, and in the valleys draining the high ground of Enville and the Clent-Lickey range, which resulted from these conditions. Most of these grade down to the Main Terrace level in the adjacent valley, and may be correlated with that terrace and thus with the third glaciation; though some seem to be still younger and to correlate with the Worcester Terrace and the Welsh Re-advance.
(b) *The Welsh Re-advance*⁷ or Little Welsh Glaciation.

The fourth and last glacier to reach our area was an extension of the Upper Severn valley-glacier down as far as Shrewsbury to which Whitehead has given the name *Welsh Re-advance*. There is strong evidence that the lowest of the important Severn Terraces, the Worcester Terrace, was being formed during this re-advance. It is the highest terrace to be recognised on both sides of the Iron Bridge gorge, and its level there shows that the gorge was then some 60 feet shallower than now.

There is no conclusive evidence in the Midlands that the cold conditions of the Welsh Re-advance were anything but a climatic oscillation in the general amelioration that caused the gradual melting of the Irish Sea glacier. Whitehead in his account of the Shrewsbury district writes as if he considered that the Irish Sea ice-sheet possibly still existed not far to the north, when the Welsh Re-advance glacier was at its maximum. There is, however, some slight evidence for interglacial conditions in the Midlands during the time between the deposition of the Main and Worcester Terraces, which, taken in conjunction with evidence in other areas (particularly the sealing by Irish Sea boulder clay of Upper Palaeolithic caves in North Wales, and the upper boulder clay on the top of the Wrexham delta-terrace, now being investigated by Miss D. S. Coates), suggests the possibility that the Irish Sea ice sheet first withdrew completely and then re-invaded the northern part of its old domain simultaneously with the re-advance of the Upper Severn glacier.

This problem is one among many relating to our glaciations that await solution, and yet can never be solved by work in one restricted area. The cry is always for accurate data in neighbouring areas. I close this address, as I began it, by an appeal for amateurs who are willing to undertake conscientiously and scientifically the recording and co-ordinating of every scrap of evidence in the district in which they live, whether it be a glacial or a periglacial one. If this were done so carefully that no temporary exposure escaped record, data would gradually, but I think quickly, accumulate by which some at least of the many outstanding problems of glacial correlation and interpretation would reach solution.

⁷ The map, Fig. 2, does not attempt to show the limits of this along the Welsh borderland, as worked out by Dwerryhouse and Miller and by Charlesworth, since they lie wholly outside the Midlands.
SECTION D.—ZOOLOGY.

THE SEX RATIO

ADDRESS BY
PROF. F. A. E. CREW, D.Sc.,
PRESIDENT OF THE SECTION.

Of the thousands of zoological papers that appear in the course of a year few surpass in interest the Statistical Review of the Registrar-General. Its pages are crowded with irresistible invitations to thought, and nowhere else can be encountered greater incentives to further inquiry through observation and experimentation. Its title and address do not disguise its real nature, for it deals with phenomena that are essentially zoological—with growth, multiplication, natality and mortality in an animal population, and with the results of the interplay of living animal and varying environment. It is, in fact, a progress report of a vast and exciting zoological experiment which we are conducting, scientifically or otherwise, with ourselves as the experimental material. For this reason alone it commands the attention of the zoologist.

But there is another and even more cogent reason why we should study this Review. Many of the data presented therein can be interpreted correctly only by such as can bring to their examination knowledge derived from a comparative study of a number of different living forms. Much concerning man must remain incomprehensible until the answers to our questions are sought amongst the structures and behaviours of other and sometimes quite lowly animals.

An excellent illustration of this contention is provided by the figures in this Review which relate to the human sex ratio. Nothing is easier than to demonstrate that for an understanding of the somewhat startling and certainly intriguing facts concerning the relative numerical proportions of the sexes in a human population we are inevitably forced to make a comparative survey of the sex ratio amongst other mammals, birds and insects, wild and domesticated, both in the open and under the controlled conditions of experimentation. In this matter of the sex ratio, to know only man is to understand nothing.

This subject of the numerical proportions of the sexes in a population is of such obvious interest to the naturalist, the sociologist, the economist amongst others, that it is not surprising to find that to it considerable attention has been paid. But so complicated are the problems that cluster round it that even yet our understanding of the significance of the sex ratio is still very incomplete. It will be remembered that Darwin (1871), in discussing the influence of natural selection on the sex ratio, made the
following observations: 'In no case, as far as we can see, would an inherited tendency to produce both sexes in equal numbers or to produce one sex in excess, be a direct advantage or disadvantage to certain individuals more than to others... and therefore a tendency of this kind could not be gained through natural selection. Nevertheless there are certain animals in which two or more males appear to be necessary for the fertilisation of the female: and the males accordingly largely predominate, but it is by no means obvious how this male-producing tendency could have been acquired. I formerly thought that when a tendency to produce the two sexes in equal numbers was an advantage to the species it would follow from natural selection, but I now see that the whole problem is so intricate that it is safer to leave its solution for the future.'

I myself belong to a generation whose thoughts and actions have been largely moulded by Darwin's opinions and attitudes. It is but natural, therefore, impressed as I am by his greatness, that I should hesitate to assume that I might contribute towards the solution of a problem that Darwin himself set aside. But recent developments in cyto-genetics have removed many of the difficulties that surrounded this subject in Darwin's time and it is, I think, now possible to re-examine the problem more hopefully. I am encouraged in this view by the writings of Fisher (1930) who in presenting his concept of reproductive value logically maintains that the sex ratio adjusts itself under the influence of natural selection in such a way that the total parental expenditure incurred in respect of each sex is equal. Accepting this argument, I propose to attempt to uncover the mechanisms that may be concerned in such adjustment.

From the pages of the Registrar-General's Report for 1935 I have torn all the information that deals with the sex ratio. The abundant tables so completely detailed show that in that year in England and Wales for every 100 girl babies born alive there were no fewer than 105.6 boys. Expressed differently, the secondary sex ratio (the sex ratio that obtains amongst newly born infants) was 105.6:100.

During the same year the sex ratio for the babies who died during the 7th-9th months of intra-uterine life was 110:100, being significantly higher than the secondary sex ratio.

The population, being classified by the Registrar-General into 5-year age groups, and the sex ratio of each of these groups computed, it is revealed in the most striking fashion that the sex ratio becomes greatly altered as we pass from the younger to the older age groups. This swing is indeed remarkable, for a numerical preponderance of males amongst the earlier age groups gives place to a numerical equality of the sexes among the 15-19-year olds, whilst amongst the 20-24-year olds the females actually begin to outnumber the males; and thereafter, as age group succeeds age group, this female numerical ascendency progressively increases until, amongst the 85's and over, there are more than twice as many women as men.

This swing in the sex ratio from high to very low, is shown to be the result of a sexually selective mortality, for the mortality tables make it clear that at all ages relatively more males are removed from the popula-
tion by death; amongst those aged 75 and over actually more females than males die for the very simple and obvious reason that amongst the individuals of 75 and over awaiting death there are far more females than males.

It would appear from these figures alone that to be born is a more dangerous adventure for the male than for the female, and that there is a sexually selective mortality which not only operates at all ages after birth to the disadvantage of the male, but which acts and possibly equally strongly pre-natally as well. The expectation of life at all ages is greater in the case of the female of the species, and the true recipe for longevity is to be born a girl. The political power of women in a democracy such as ours, which pretends to disregard sex differences, is much less than that which their numbers could command.

A considerable number of other facts and observations concerning the human sex ratio and relevant to the present discussion are easily found in the abundant literature that deals with this particular subject. It is generally accepted, for example, that the sex ratio amongst abortuses is higher than that amongst still-births, and there is sufficient reason for holding the view that the sex ratio amongst abortuses of the earlier months of intra-uterine life is much higher than that amongst those of the later months. It has been shown that the secondary sex ratio is influenced by urbanisation, being lower in county boroughs than in rural areas. The secondary sex ratio would seem to be affected by social upheavals. It is commonly held, for example, that in those countries directly engaged in the Great War the secondary sex ratio was high immediately following the cessation of hostilities and higher immediately after than immediately before the War; neutral countries affected commercially by the War experiencing the same phenomenon, though not to the same extent. The secondary sex ratio is highest amongst the first-born, and declines with increasing size of family in a curvilinear manner. It is influenced by migration, the migrants having a higher or a lower secondary sex ratio than their relatives who remain in the homelands. Usually it is lower amongst illegitimates than amongst living children born in wedlock.

As a rule it is lower amongst coloured people than amongst the whites amid whom they live. It is affected by social status, being higher in the upper and middle classes and lower amongst the unskilled workers. In places and in periods where infant mortality is high the ratio of boy deaths to girl deaths is low, and where there is a low rate of infant mortality the death rate of boys is relatively high. With the reduction of infant mortality that has occurred within recent years there has been a marked relative increase of boy deaths. The sex ratio at death amongst infants during the first year of life varies with the age of the infants: for the very young it is high, but decreases during the year.

A consideration of these facts must ultimately lead to the conclusion that in the case of man, for some reason or other, the male, in virtue of his maleness, is less viable than the female, so that, under unfavourable circumstances, both pre-natally and post-natally, the male, because of this greater inherent fragility, suffers more easily and more severely than does the female, and is removed from the population by death in greater numbers. Furthermore, since this selective elimination of the male occurs
before as well as after birth, it follows that since the secondary sex ratio is 105:100, the primary sex ratio (that which obtains at conception) must be higher than this, high enough, presumably, to allow for the wastage that occurs.

This suggested explanation of the difference between the primary and secondary sex ratios and of the greater mortality of the male would seem to accommodate every demand made upon it. Thus: abortion is far more common than is usually recognised. Out of every 100 conceptions only 78 can be expected to yield living offspring. The incidence of abortion is higher during the earlier months of pregnancy. If, then, the conditions which attend pregnancy are unfavourable to the embryo and foetus, foetal death is made more probable, and if the male foetus is less viable than the female, more males than females will perish. Under such circumstances, the secondary sex ratio will be low. The sex ratio amongst abortuses will be higher than that amongst still-births for the reason that the differences in viability between male and female are greatest during the earlier stages of intra-uterine development. Movements in the secondary sex ratio can therefore be used as a measure of the success or otherwise of the social services, of slum clearance, of the general health of a community. The secondary sex ratio is lower in county boroughs than in rural areas for the reason that abortion and still-birth are more common in urban populations. The greater frequency of abortion implies a higher male mortality, and therefore a lower sex ratio amongst those who are born alive. The secondary sex ratio is thus a biological yardstick with which town and country may be measured. It is highest amongst first-born for the reason that the incidence of abortion and miscarriage is higher in large than in small families; thus, in a dwindling population, the secondary sex ratio will be high. It differs in different countries for the reason that in them there are different standards of living and of personal and public hygiene so that abortion and miscarriage are commoner in one country than in another. It is influenced by migration because of the reactions of the migrants to the new conditions. If the migrants move from a relatively harsh environment to a relatively generous one, so that the conditions associated with child-bearing are greatly improved, it is to be expected that there will be fewer abortions and miscarriages, and so relatively more male births and a high sex ratio. This holds true of Northern European immigrants in the United States of America. On the other hand, Southern European immigrants have a lower sex ratio than their kin remaining in Europe for the reason that the new conditions are to them less favourable than were those in the countries from which they came. They reinforce the lowest social categories, and a harsh European environment is replaced by one even harsher. Thus the secondary sex ratio can, in such circumstances, be used as an index of the success or otherwise of immigration. It is lower amongst illegitimates than amongst legitimates for the reason that abortion and still-birth are commoner amongst the former for very obvious reasons. If it is not lower among illegitimates then it is to be assumed that in that particular community illegitimacy is not regarded as an unforgivable social error. It is lower amongst coloured people than
amongst their white neighbours if and when the standards of personal and public hygiene of the two sections of the community differ at all markedly. Usually the standards of the coloured peoples are lower, and for this reason abortion and miscarriage amongst them are more frequent. It is affected by social status for the reason that in general the higher the status the more generous is the environment, the smaller the family and the greater the attention given to the child-bearing mother. The differences between the social classes in respect of the sex ratio are to be related to differences in the incidence of abortion. In a class-less state with a high standard of living, the sex ratio will be uniformly high. The relation between primary and secondary sex ratios is unaffected when infantile mortality generally is high, and is disturbed when this is low for the reason that high infantile mortality indicates the action of death-dealing diseases of such potency as to overwhelm any difference in respect of viability on the part of male and female. Such diseases kill both boys and girls without discrimination. Under these circumstances, since both boys and girls are removed, the sex ratio is unaffected. Low infantile mortality, on the other hand, implies relatively mild attacks of disease-provoking agencies which discriminate between male and female, leaving the female untouched in virtue of her greater constitutional strength, but removing the weaker male to yield a low sex ratio. Since, in this respect, the sexes are so different, it follows that in the case of an ailing male child the doctor is called upon to treat not only the pathological condition but also the condition of maleness.

The disturbance of the secondary sex ratio that is commonly supposed to be associated with protracted war is not so easily explained. If it is indeed the case that there is a real and significant rise in the sex ratio associated with war then the explanation would seem to be that under the conditions that exist the incidence of abortion and miscarriage falls. It has been suggested that the lengthy absences of husbands with a consequent reduction in the frequency of intercourse and therefore of pregnancy mean rest and repair for the wives and the attainment of a greater degree of physiological fitness. This of course would lead to a lowering of the incidence of abortion in those cases in which pregnancy did occur. Furthermore, war is associated with a rise in the marriage rate, and this means relatively more first babies, and the high sex ratio that obtains amongst such. However, this suggestion of a modification of the secondary sex ratio associated with war demands further examination, for it has been shown that if the sex ratio of a population is traced over a long period of time it is usual to find evidences of a definite secular trend, upwards in some countries, downwards in others (Russell, 1936), so that it may be that the sex ratio associated with war can be evaluated only when it is studied in relation to this movement of the sex ratio generally which can be seen only if 100 or more years are reviewed.

In explanation of the observed inequality in mortality and longevity of the sexes in man a number of suggestions have been offered. To account for the particularly high mortality of male infants around the time of birth emphasis has been placed upon size differences between the sexes. Typically the male is the larger, with the bigger head and with
bones more completely ossified, and so, as would be expected, it is the male that suffers more from birth injuries and from the epilepsy that follows upon such. The sex ratio of such cases is approximately 160 : 100. There are other causes of death which operate almost exclusively upon one sex: hernia is a cause of death of male infants, gonococcal infections are restricted almost exclusively to the female infant. But the explanation of this is to be found in a consideration of the anatomical differences that distinguish the sexes at birth. Such sex-limited conditions obviously cannot provide an explanation of the difference in the sex incidence of death among early abortuses, and, in any case, they lose their significance when the tables in the Registrar-General’s Annual Review giving the causes and the sex incidence of death are examined, for it is seen that from all causes there is everywhere a general proneness on the part of male infants to die in greater numbers, and that in general the earlier in life the onset of a disease, the higher is the sex ratio among its fatal cases. This is true of infectious as well as of other diseases, and the only possible explanation for this would seem to be that the differences between the sexes in respect of capacity for continued life is greatest in early infancy.

Violent deaths remove twice as many males as females from a population in the course of a year, and therefore necessarily distort the sex ratio among certain age groups, but murder, suicide, deaths on the road, occupational accidents, warfare and migration cannot possibly explain away the gentle swing in the sex ratio from conception to extreme senescence. There is no doubt whatsoever that the whole course of sex mortality in pre-natal life, in infancy, and in all subsequent age periods is consistent with the view that the male in man is the inherently weaker sex, more prone on account of his relative constitutional weakness to developmental anomalies, to congenital debility and to death from diseases of all kinds.

This being so, it is necessary to contrast male and female in order to determine what fundamental differences distinguish them, and to decide which of these may be held responsible for the observed differences between the sexes in respect of viability.

Male differs from female in genetic constitution. He is heterogametic, possessing but a single X-chromosome and elaborating two kinds of gametes, X-chromosome-bearing and Y-chromosome-bearing respectively. The female is constitutionally homogametic, possessing two X-chromosomes and therefore elaborating ova all of which are alike in that each carries one X. In respect of X-borne genes the male is equipped with a single set, the female with two. It follows from this that in the female a mutant recessive gene in one X can be cancelled out by its wildtype dominant allele in the other, whereas the same recessive gene in the single X of the heterogametic individual is unchecked and unrestrained and is expressed to produce its full effect. Upon this firm basis of ascertained fact, the sex-linked lethal theory, which seeks to account for the sexually selective mortality and the swing in the sex ratio, has been built. It has been advocated by Lenz (1923), Gunther (1923), Geiser (1924–5), Huxley (1924), Schirmer (1929) among others, and had its beginning as long ago as 1912 when Morgan first drew attention to the lower vitality
of the mutant white-eyed stocks as compared with that of wildtype *Drosophila melanogaster* and when, in the following year, Hyde, using wildtype and truncate flies produced evidence which seemed to show that duration of life had a genetic basis. In 1916 Morgan and Bridges listed all the known mutants in the X-chromosome of *Drosophila melanogaster* and noted for many of them their effect upon the duration of life. They found that certain mutant genes very effectively reduce the viability of the males and alter the secondary sex ratio and discovered a number of sex-linked ‘lethal’ genes which caused the death of all males carrying them. Later Pearl and Parker (1921) proceeded to demonstrate the constancy of definite degrees of mean longevity of inbred stocks of *Drosophila*. They found, for example, that their ‘Old Falmouth’ wild-type males had at emergence an expectation of life of 41·0 days, whereas quintuple males with 5 mutant genes had one of only 14·2 days. Crosses between the two stocks were made by Pearl, Parker and Gonzalez (1923), and in the F2 definite evidence of segregation presented itself. Gonzalez (1923) further studied the mean duration of life of strains of *Drosophila* possessing 1, 2, 3, 4 and 5 of these mutant genes, and ascertained that in so far as their effect on duration of life was concerned, the individual mutants behaved as units.

Since this time a great mass of information concerning these matters has been accumulated, and it is clear that these lethals exist in considerable numbers in such animal and plant stocks that have been subjected to genetical experimentation. They are not vague abstractions invoked by the diagnostically destitute to explain away a mortality that they cannot comprehend: they are genes which can be mapped and which have an effect upon the secondary sex ratio that can be predicted. They can be incorporated into and rejected from a genotype at will and in this way the dimensions of a secondary sex ratio can, within limits, be experimentally controlled. Their presence and wide distribution in wild populations have been amply demonstrated, and no doubts remain that they are responsible, in part at least, for the higher mortality of the heterogametic sex, both pre- and post-natally.

But there are genetic differences between the sexes which are sex-limited, not sex-linked. Levit (1935) has presented a very considerable body of evidence which shows that many defects and derangements in man, formerly regarded as recessives, are partial irregular dominants, and that many of these are more often and more completely expressed in the male than in the female. Furthermore, he has shown that many of these characters which previously had been classified as sex-linked are in reality sex-limited, being expressed only in the male. He explains the greater manifestation of heterozygous genes, corresponding to defects, in the male, on the ground that in man selection is less intense among males than among females so that such genes would tend to accumulate in the male as would also genes causing sex-limitation. From an examination of the sex ratio among the relatives of the father and mother Levit has been led to the conclusion that few of the male deaths at or before birth are due to sex-linked lethals. From this it would appear that though sex-linked lethals are certainly responsible for some of the differences in male
and female mortality rates, it is much more likely that sex-limited defects and derangements, expressed either before birth or in senescence, are also heavily concerned.

Sex differences in chromosome constitution may imply more than a difference in respect of sex-limitation and of sex-linked lethals; they may mean also a difference in genic balance. Two X-chromosomes together with two sets of autosomes include a gene association different from that which is resident in one X-chromosome and a Y-chromosome plus two sets of autosomes. The work of Gowen (1931) who studied the duration of life in males, females, triploid females and sex-intergrades of Drosophila melanogaster to find that the average length of life was 33.1, 28.9, 33.1 and 15 days respectively, can be regarded as providing evidence that differences in chromosome balance is a factor in determining the span of life. It may be that this difference in genic balance between male and female is itself a cause of unequal mortality, though it is difficult to regard the male as being less well balanced genically since he has endured as long a course of selection as has the female and it would be expected that dosage compensation would ensure a proper balance in each sex regardless of differences in dosage ratios.

There are other differences, metabolic and physiological, which quickly appear in development and which, in turn, give rise to endocrinological differences which, when once established, take charge of further differentiation and the maintenance of sexuality in the higher forms. The initial genetic constitution would seem to determine which of two alternative types of differentiation shall occur—either toward testis formation, or else toward ovary formation—and, with the incoming of the gonad and the rest of the endocrine system, maleness or else femaleness becomes finally and firmly established. These two states or conditions are to be distinguished by sustained differences in oxidation rate.

It will be remembered that Geddes and Thomson (1889), having looked widely upon living things, were driven to the conclusion that males are predominantly catabolic, females anabolic, that the deep constitutional difference between the male and the female organism which makes one a sperm-producer and the other an egg-producer was due to an initial difference in the balance of chemical agencies. This hypothesis has been much refined and elaborated by Riddle (1931) who assumes that the genes exercise their influence on developing sexuality by establishing higher or lower oxidation rates. He points out that if sex differences rest primarily on prolonged and sustained differences in the rate of cellular oxidation during the earliest phases of development, this difference should often be well expressed in adult stages as well and should manifest itself in adequate measurements of metabolic rate and in various states or conditions of the blood and tissues which restrict, indicate or accompany metabolic rate. Adequate measurements of basal metabolism of the sexes have been made in the young human (Benedict and Talbot, 1921), adult human (Benedict and Emmes, 1914, and also GePhart and du Bois, 1916), in the adult fowl (Mitchell, Card and Haines, 1927), the rat (Benedict and MacLeod, 1929) and in the ring dove (Riddle, Christman and Benedict, 1930). In every case the higher metabolism, from 3 to
14 per cent., has been found in the male. Because of their relationship to respiration the erythrocytes and hæmoglobin might be expected usually to show a sex difference. Adequate measurements of both erythrocyte number and hemoglobin content have been made on the adult in man (Haden, 1922, Rud, 1923), in the fowl (Blacher, 1926), pigeon and ring dove (Riddle and Braucher, 1931), and in every case the higher erythrocyte amount, 2·3–3·1 per cent., and the higher hæmoglobin value, 7–35 per cent., is found in the male.

In the light of these and similar observations it is reasonable to expect that the higher metabolic rate of the male should render him less resistant to unfavourable conditions and more prone to death. That this expectation is justified is shown by the results of a considerable number of varied experiments, the following of which are cited as examples.

MacArthur and Baillie (1929) found that at 28° C. the mean duration of life of the females of Daphnia magna exceeded that of the males by 33·35 per cent., by 15·82 per cent. at 18° C., and by only 0·43 per cent. at 8° C., and they further demonstrated that this extreme response of the males was probably a factor of their metabolic level. Riddle, Christman and Benedict (1930) found that the basal metabolism of male pigeons was more easily and extremely affected by such conditions as unusually high temperature and low oxygen supply than was that of the females. Essenberg (1923) showed that the males of the sword-tailed minnow Xiphophorus helleri are 2–25 per cent. more susceptible to KCN, alcohol and extremes of temperature, whilst Hildebrand (1927) found by direct test that the males of Gambusia are much less resistant to high temperature, altered pH, KCN and oxygen deficiency.

The metabolic theory is, at the present time, somewhat crude, lacking the precision and smoothness that distinguish the alternative and attractive sex-linked lethal theory, but nevertheless in it there lies truth. It is to be expected that, with advances in our knowledge of endocrinology, and with the increasing manufacture of synthetic equivalents of the elaborated products of gonad, pituitary, thyroid and the rest, we shall soon be equipped with the means of exploring completely those physiological differences between the sexes which seem to be connected with differences in mortality, and, moreover, it will then perhaps become possible to repair by chemical means the deficiencies which maleness now confers upon its exhibitors.

It is desirable at this stage to find out if the sex ratio of man is peculiar, or whether the facts and observations concerning the human sex ratio apply also and equally to that of other living forms.

A great mass of data relating to the secondary sex ratio in animals of economic importance has been accumulated, and though herd and stud books are, for various reasons, inclined to be somewhat inaccurate, the records therein do possess a certain value. An examination of these shows that in the case of the horse the secondary sex ratio has been found by all who investigated it to be low, so also has been that of the sheep. That of cattle has a wide range, from very low to very high, whilst that of the pig and of the dog has always been found to be high. But, from the point of view of the present study, the secondary sex ratio by itself possesses
little value. The fact that it is never equality is of course a matter of considerable interest, and invites speculation, but unfortunately the figures relating to pre-natal and early post-natal death are but few, and, for the most part, were garnered many years ago. However, it is the case that in all instances in which figures for the sex ratio of still-births amongst these animals of the farm have been examined they always show that this is higher than that amongst live births. Thus Goehlert (1888) gives 106 : 100 for still-births, and 96·5 : 100 for live births amongst horses. In cattle, Lillie (1916) found the sex ratio amongst still-births to be 134 : 100 ; Jewell (1921) 123 : 100, that for live births being 100–110 : 100. Parkes (1925), examining the sex ratio amongst pig foetuses classified into different weight groups, found that the sex ratio was very much higher amongst them than was the standard secondary sex ratio, and, further, that the size groups showed an inverse correlation between male percentage and the stage of development. He concluded that the primary sex ratio in the pig must be about 160 : 100. Krizenecky (1935) in a review of the sex ratio in the pig gives that of still-births as 119 : 100, compared with 101·8 : 100 for live births.

The figures for post-natal mortality from natural causes amongst these animals are of course exceedingly rare, for it is man himself who here wields the sickle. For this reason the tertiary sex ratio (that which obtains amongst an adult population) provides no information of any value to the present discussion. However, my colleagues have provided me with figures which show the relative male and female wastage amongst our pigs between birth and weaning. The secondary sex ratio amongst 2,336 pigs is 104·9 : 100, whereas that amongst the 1,489 which remain alive at the time of weaning has fallen to 97·4 : 100, the percentage loss amongst the males being 38·6, that amongst the females, 33·7. These figures suggest that the pre-natal mortality in the pig which discriminates against the male is continued at least up to the time of weaning.

Thus, as far as they go, the figures relating to the mammals of the farm without exception suggest that the male amongst them shares with the male of man a relative frailty and endures a selective elimination both before and after birth.

The laboratory rat and mouse have provided records which, though far less numerous, are more reliable than those derived from stud books. The secondary sex ratio of the albino rat is accepted as being roughly 106 : 100, that amongst still-born rats was found by King (1921) to be 129·3 : 100. In the case of the mouse the secondary sex ratio for the ordinary albino as recorded by different investigators is round about equality with a slight suggestion of male excess. There is some difference of opinion concerning the relation of pre-natal mortality and the secondary sex ratio in this animal. The earlier observations of Parkes (1924) suggested that there was a considerable pre-natal mortality and that this was sexually selective, falling preponderantly on the male. Continuation of this study, however, failed to support this conclusion. Furthermore, McDowell and Lord (1925), in the case of their own mouse stock, have shown fairly conclusively that during gestation there had been no continuous sexually selective elimination of one sex or the other. In the
case of the laboratory mammals, therefore, it may be accepted that though in certain stocks there is no evidence of a selective pre-natal mortality, yet in others in which it undoubtedly occurs it is the male that is removed in greater numbers.

In the case of birds there is much that is anecdotal and a certain amount of information that has been derived from experimentation. It will be remembered that Darwin's correspondents assured him that male birds were caught in greater numbers than were females, and that he accepted this presumed preponderance of males in nature as a fact supporting his theory of sexual selection. Pelseneer's (1921) summary closes with the statement that in the known cases where observation had been possible an early excess of males at hatching and in young birds may be preserved into adult life, but becomes less marked owing to the shorter life and higher mortality of the males, and is often followed by an equality of the sexes or even by a numerical preponderance of females. Darwin accepted the view that in the domestic pigeon there is good evidence either that males are produced in excess or that they live longer, and that the hen is generally the weaker of the two and more likely to perish. Cole and Kirkpatrick (1915) found a secondary sex ratio of 105 : 100 in the pigeon and recorded that post-natally there was an early period with an excess of male deaths followed by an adolescent and reproductive phase with a slight excess of female deaths, but that, on the whole, there was no significant change of the sex ratio with advancing age. Whitman's figures (1919) for the Japanese turtle dove, presented by Riddle, show that the male is often the longer-lived, whilst Haig Thomas and Huxley (1927) found that in pheasant species crosses there was a predominance of males at hatching and also a large and distinctive excess of male deaths both before and after hatching, so that a secondary sex ratio of 67·1 per cent. males became reduced to 50·1 per cent. in the adult, they concluded that in the case of these pheasant crosses the early post-natal mortality of the male is much greater than that of the female.

Concerning the sex ratio of the fowl there is an abundant literature, much of which has been summarised in the papers to which reference is now made. Landauer and Landauer (1931) computed that amongst 67,993 live born chicks the percentage of males was 48·77, whereas among those dying during the first eight weeks of life it was 52·7 ± 0·5. They therefore concluded that in the fowl, as also in man, post-natal mortality is higher amongst males and that if any differential mortality during embryonic development occurs it is the male that suffers more. But Byerley and Jull (1935) present an even greater body of data. They hold the view that data on embryonic mortality were dismissed as inadequate by Landauer and Landauer, and largely ignored by MacArthur and Baillie (1932), and show that in the literature are to be found records of 6,864 dead embryos of which 48·59 per cent. were males. They themselves examined a further 17,989 dead in shell to find among these 47·56 per cent. males. Thus, among the whole 24,853 dead embryos there are only 47·85 per cent. males, a highly significant deviation from equality.

Adding their own figures to those in the literature they find among
96,008 live born chicks, 49.17 ± 0.11 per cent. males—a figure still significantly lower than 50 per cent., so that it would appear that in spite of the fact that more females than males die before hatching there is still a slight preponderance of females among the live born.

As regards early post-natal mortality neither Jull (1931) nor Byerley and Jull (1935) could find any evidence to show that this was in any way differential between the sexes. There is no reason why there should be if only viable chicks are hatched and if the conditions of brooding are such as not to discriminate against one sex. In order to determine which sex is less viable during early post-natal life, it would be necessary to keep the chicks under less favourable conditions; at the present time the techniques of artificial incubation are not so highly developed as are those of artificial brooding.

These conclusions attach to themselves a particular importance for the reason that in birds the heterogametic sex is the female. A comparative study of the sex ratio and sex incidence of mortality in mammals and birds might be expected, therefore, to determine to what extent the heterogametic constitution itself is connected with mortality. If in mammals it is the male and in birds the female that is found to be the more fragile, then it becomes possible to assert that it is the heterogametic sex that is the less viable and to seek the cause of this relative inviability in the heterogametic constitution. If, on the other hand, it should prove in both mammals and birds to be the male that is removed by natural death in greater numbers, maleness itself must be held to be the cause.

The figures for the fowl seem to show that it is the heterogametic sex upon which death falls more heavily pre-natally so that it becomes possible at once to decide that in the heterogametic mechanism itself a factor of importance is to be found. But more information concerning birds generally is urgently needed.

Geiser (1923) in reviewing the literature dealing with the sex ratio in fish found that in populations taken at birth the sexes were either nearly equally represented or else showed a slight excess of females, and that in older populations the females were always more numerous; in some instances greatly so. But the evidence loses a great deal of its value for the reason that the sex chromosome constitution of such fish as the plaice, salmon, smelt, dog-fish and top minnow has not yet been determined, so that it is impossible to relate the above findings to heterogamety.

Concerning insects many records have been published showing that the normal male does not live as long as the female. Arendsen Hein (1920) found that among 13,754 young pupae of the meal worm beetle taken at random the sex ratio was 100 males : 100.3 females. In a series of 32 experiments he ascertained that in this species the male lives on the average 60 days, the female 111. Pearl (1923) found that in the case of Drosophila melanogaster (male heterogamety) the survival relations of the two sexes were exactly like those in man; at practically all ages in Drosophila the number of survivals at any given age is higher amongst the females than amongst the males. The mean duration of life for the male is 31.3 days; that for the female 33.0 days.

There is a series of papers by Rau and Rau (1914) dealing with large
saturnid moths (female heterogamety) which are always quoted as supporting the contention that in this group males commonly outlive the females, but, in point of fact, an analysis of their figures by MacArthur and Baillie (1932) shows that the contrary holds true for five out of six of the species. Graf (1917), working with the potato tuber moth, found that the males died first in 221 out of 275 pairs in the experiment, and concluded that the length of life of males is less than that of females. In the gypsy moth (female heterogamety) Goldschmidt (1917) records that the males are so precocious and so short-lived that they are often gone before the later females are ripe. Very full information concerning the mortality of the sexes of the codling moth (female heterogamety) is contained in certain publications of the United States Department of Agriculture. The studies were made on a very large scale, repeated over many years and at stations widely separated, covering all sections of the continental United States. The most useful data from this source include the records of longevity of imagoes from observations on large numbers of mated moths reared in their natural sex ratios in large out-door oviposition cages. From the figures given it is evident that at all stations and in all generations (excepting only the first broods) the males are the shorter-lived. The weighted average duration of life for females is 10.23 days, that for males 9.40 days. The difference between this is over twenty-five times its probable error and is highly significant in view of the large number on which it is based. MacArthur and Baillie (1932) use these figures very effectually to maintain their conclusion that Lepidoptera afford no exception to the rule that the larger destruction and shorter life of males, irrespective of whether these be homo- or hetero-gametic, cause them to become relatively fewer at advanced ages.

A multitude of other references could be quoted, but were this done nothing very essential to this discussion would have been added. Everywhere one finds support of a kind for the contention that the male, irrespective of his actual sex chromosome constitution, is the shorter-lived.

Though much remains unclear, demanding further and more critical examination, enough has been gleaned from this necessarily incomplete survey to show beyond all doubt that there is nothing unique about the human sex ratio and that the factors which operate to distort it are exactly those which produce the same results in other forms. Sex-linked lethals and other recessive disadvantageous X-borne genes are undoubtedly concerned in the production of a sex incidence of mortality that bears more heavily upon the heterogametic sex. But it is impossible, in the face of all the evidence that has been presented, to conclude that all the inequality in mortality and longevity between the sexes is due to the action of such genes. Wildtype stocks of Drosophila shown to be free from expressed lethals have exhibited the usual sex differences in longevity. There are autosomal genes, as Gonzalez (1923) has shown, which completely reverse the usual mortality of the sexes and allow males to outlive the females by a very significant number of days. So that mortality and longevity are controlled through the whole genetic and environmental complex; they are not different and separate characters, but expressions in time of the organisation of the body.
As a general rule, the males of all groups, except those derived from wide crosses in which genic balance is more likely to be unusual, appear to show a relatively low viability, irrespective of their homo- or heterogamety, and the difference in the death rates of the sexes appears to be as much correlated with sexuality itself as with any particular type of chromosome or gene equipment. That this should be so is perhaps not surprising when the relative reproductive values of the sexes are compared. The major task of one generation of gamete producers is the production, economically and efficiently, of a succeeding generation that numerically will be in harmony with the conditions and resources of the habitat. That of the females of a generation is the production of the requisite number of ova; that of the males the production of spermatozoa in numbers sufficient to make the fertilisation of every available egg highly probable. The number of spermatozoa required will be determined by many factors—e.g. the variety of the fertilisation process, the pre-natal and post-natal relations of mother and offspring, the relationship of male to female in respect of parentage. If the male is merely a fertilising agent, then economy and efficiency are observed if the male dies in coitus or is for other reasons shorter-lived than the female so long as there are more or less equal numbers of males and females of the age when fertilisation occurs. If the male is concerned with the protection of and food-finding for the female and her young then the length of life of the male might be expected to be related to the duration of the period of dependency of the young upon the parents and of the female upon the male, and it might reasonably be assumed that when the male has served his purpose he would be removed so that savings in food energy could be effected and used for further reproduction.

In the light of the facts and observations that have been presented, it is desirable to examine Table 31, Volume 2, of the Report on the Census of Scotland, 1931. Here it is seen that in this human population, though between the ages of 0–14 there were more males than females, and between the ages of 20–100 there were more females than males, the sex ratio of those in the population between the ages of 15 and 19 was equality. So, also, in the Registrar-General’s Annual Review for 1935 will it be found that among those aged 15–19 is the sex ratio most nearly equality. It can be stated, therefore, that in the case of these human populations the sex ratio is equality only amongst those who stand at the threshold of their reproductive prime. This fact is surely not without significance. The age group in which the sex ratio is equality consists of those who, biologically if not socially, are newly equipped for ardent reproduction. Amongst them there is no surplus: there are equal numbers of males and females. If, during the biological evolution of man, pair-mating attached to itself a definite and positive value, it would be expected that all the mechanisms concerned in the establishment of a sex ratio of near equality among the 14–19 age group would, through selection, come ultimately to be related harmoniously to this end.

Implied in this suggestion is yet another: that in the case of any population of living things, and under the conditions that exist in any given place and at any given time, there is an optimum sex ratio amongst
those of the ages associated with the fullest expression of the reproductive function, and that through selection all the mechanisms, whatever they may be, which influence this are fashioned into harmony with this "reproductive" sex ratio. It is necessary, therefore, to discuss the meaning in biological philosophy of mutation, sex and heterogamety, all of which are intimately concerned.

Mutation is a mechanism that has become adapted and elaborated for the provision of material possibilities of evolutionary movement. It takes the form of the replacement of one gene by an allelomorph:—the substitution of a gene that, having been tested and found worthy, has come to be in harmony with the rest of the genotype, and through this with the conditions of the external environment, by another, the merits of which have yet to be determined. More often than not, therefore, mutation implies a disturbance of an equilibrium within the genotype itself, and between this and the external environment. It is usual, therefore, to find that mutation leaves the genotype less in harmony with the existing external conditions than was that which it has replaced. Mutation, the inception of a new heritable variation, thus usually equips its possessors with a handicap, imposing on them a disadvantage that can range from inconvenience to complete lethality.

Sex is the mechanism that has become adapted for the dispersal of a mutant gene amongst a population. Through its exercise a new gene can become incorporated into a variety of genotypes, and thus given the opportunity of finding itself associated with other genes with which it can interact. It is established that the quality of the action of a gene is largely determined by this interaction with others, for, as judged by its effects upon the life processes of the zygote, it can exhibit disadvantageous properties when in one gene association, advantageous when in another. For the quiet dispersal of a mutant gene in this way it is necessary that it should be recessive, initially at least, to the gene that it has displaced, for then it can pursue a cryptomeric existence for a considerable period of time.

If the great usefulness of sexuality lies in the opportunities it provides for variety in gene recombination and for the exercise of selection then its advantages will be best exploited when, among those about to reproduce, there is a sex ratio of equality. This observation would not seem to apply to those instances in which gene combinations that are common or are exceedingly rare are concerned, but a sex ratio of equality among the parents would seem to provide the greatest variety of recombinations in the offspring in the case of gene combination of intermediate rarity. Be this as it may, a device for the production of a sex ratio of equality has certainly been elaborated.

Heterogamety is a mechanism that has become adapted for the production of a primary sex ratio of equality. In its evolution in the higher forms it has taken the form of the replacement in one sex of an X-chromosome by a wholly or largely non-homologous Y-chromosome. The heterogametic sex, therefore, now possesses one X-chromosome, the homogametic, two. An indirect result of this evolution has been that a recessive mutant gene in the differential segment of the X-chromosome
is at once uncovered in the case of the heterogametic individual, and so, if in its action such a gene is disadvantageous, deleterious or lethal, to it no time is allowed for the finding of modifying company and for the pursuit of its own evolutionary development. It is expressed and tested within a very short time of its first appearance, and should it cripple or kill, it is the heterogametic sex that is affected. In this way the sex ratio becomes modified, for the heterogametics either die before birth or else their early post-natal mortality is greater than is that of the homogametics. It is somewhat surprising that so few sex-linked lethals have so far been discovered in mammals. It would seem that the differential segment of the X is relatively insignificant and that the crossover portion, which could not yield a differential mortality since its genes would not automatically be expressed in the male, is relatively large.

It is thus possible to look upon the inequality in capacity for continued life between the sexes as being partly of the nature of an evolutionary oversight due to a lag in the development of a harmonious relationship between the mechanisms of mutation and heterogamety. But this disharmony has been repaired by the invention of a supplementary device which can provide a compensatory primary sex ratio, high in those species with male heterogamety, low in those in which the heterogametic sex is the female. It is established that in many, though not in all, mammalian stocks, the primary sex ratio is much higher than is the secondary, and it is in such stocks that there is much sexually selective mortality operating to the disadvantage of the heterogametic sex. This being so, it seems reasonable to entertain the view that these three variables—the primary sex ratio, a sexually selective pre-natal and early post-natal mortality and the optimum reproductive sex ratio—are somehow related, the dimensions of the first being connected with the amount of the second. Should this prove to be the case, then it would follow that in general the greater the incidence of mutation, the more common the sex-linked recessive lethals and the greater the difference in the sex incidence of mortality in adolescence in a stock with male heterogamety, the higher will be the primary sex ratio, and, conversely, the rarer mutation is, the fewer the lethals and the less the difference in the sex incidence of mortality between conception and reproductive prime, the nearer to equality will this primary sex ratio be.

This suggestion, of course demands that there should be genes which affect the functioning of the heterogametic mechanism, and also that it should be possible, by continued selection, to modify the primary sex ratio of a stock. This will be equality when the heterogametic sex elaborates its two kinds of gametes, X- and Y-chromosome-bearing respectively, in equal numbers, and when both of these are equally functional in fertilisation. Conversely, the primary sex ratio will be removed more or less from equality if and when the two forms of gametes are not produced by the heterogametic sex in equal numbers, or when, between these two forms, there is functional inequality. The fact that in those instances where the primary sex ratio is not equality it is the Y-bearing gamete that is either produced in greater numbers or is greatly advantaged in fertilisation, so that more XY than XX gametes are pro-
duced, is of great interest in view of the observed fact that it is the XY zygote that suffers more through the action of sex-linked lethals.

It has been shown (King, 1919) to be possible, by continued selection within an animal stock to produce high and low sex ratio strains, and thus it would appear that there are genes which can be concentrated in a genotype which, in their action, influence the heterogametic mechanism affecting either the relative production of the two kinds of gametes produced by the heterogametic sex or else their relative functional ability. If, as seems to be the case, the male in many forms and irrespective of his chromosome constitution is the weaker sex, then in those instances in which the male is homogametic, an excess of X-chromosome-bearing ova is demanded from the hetero-gametic females or else there must be some form of selective fertilisation, the X-ova being more often or more readily fertilised.

That genes which lead to the production of X- and Y-bearing gametes in unequal numbers do exist is shown very clearly indeed by the work of Sturtevant and others. One such gene was discovered as long ago as 1922 (Morgan, Bridges and Sturtevant, 1925) in a strain of Drosophila affinis in which occasional males were found to produce families consisting almost entirely of females. A definite X-borne gene was suspected. Gershenson (1928) found a similar gene in Drosophila obscura, and showed that it was indeed resident in the X-chromosome. A male carrying this gene produces very few sons, regardless of the genetic nature of his mate. More recently (1936) Sturtevant and Dobzhansky have found that his gene has a very wide geographical distribution in both races of Drosophila pseudo-obscura, that it is sex-linked, lying in the right arm of the X-chromosome, and being associated with a small inversion. Cytological study has shown that in these cases the X-chromosome undergoes equational division at each meiotic division, whilst the Y-chromosome degenerates with the result that a male carrying this gene produces nearly all X-sperm instead of the usual 50 per cent. It is to be expected, of course, that a sex ratio gene of this kind would be discovered only if its effects upon the sex ratio were profound. But the existence of such genes permits us to assume that other genes of the same kind, having less severe effects upon the heterogametic mechanism, also exist and are responsible for minor distortions of the sex ratio. If such genes do exist, then of course, they can be incorporated into, or extruded from a genotype, and upon them selective agencies can work their will. These sex ratio genes may perhaps provide a partial explanation of the observation that hybridisation commonly is attended by marked distortions of the secondary sex ratio. Such hybridisation in man (Pearl and Pearl, 1908), in the mouse (von Guaita, 1898, 1900), and in the rat (King, 1911), for example, has given a secondary sex ratio much higher than those of the parental stocks concerned, as might be expected if these had through time come to possess different sex ratio gene complexes. It does not seem reasonable to suppose that heterosis itself could produce such a result.

But all this is so much speculation, and the only justification for toying with such ideas is that criticism may be aroused and experimentation launched. I have presented evidence to show that three possible causes
of sex differences in mortality have to be considered: (1) sex-linked lethals, (2) sex-limitation of defects and derangements, and (3) sex-dimorphic physiological and endocrinological differences. It seems probable that sex-linked lethals play only a minor part and that the defects and derangements that have come to be manifested only or more completely in the male owing to his relative unimportance in respect of propagation, constitute the major cause, though as yet too little is known of sex differences in respect of hormones and their effects to permit us to regard these as unimportant. For your pleasure and my own I have attempted to construct a thought-model of a genetic mechanism that could yield what I have called an optimum reproductive sex ratio ranging as this may from equality to the grossest inequality. I have tried to reconcile the views of the geneticist and of the physiologist out of whose disputation has emerged a clear recognition of the need for a closer collaboration. I have shown, I hope, that the problem of the human sex ratio must be studied not only in the office of the statistician but also in the laboratory of the experimental biologist and in the open country, and I have stressed the view that out of the secondary sex ratio can be fashioned an instrument of precision by the use of which a human society may measure the quality of its structure.

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SECTION E.—GEOGRAPHY.

THE CHANGING DISTRIBUTION OF POPULATION

ADDRESS BY

PROF. C. B. FAWCETT, D.Sc.,

PRESIDENT OF THE SECTION.

The changes which form the subject-matter of this address are obviously of such importance, and so directly geographical, that the choice of the topic for this Section needs no apology except on the score of its magnitude. Unfortunately, reliable statistical evidence of such changes is still inadequate. The taking of systematic and regular censuses began, on both sides of the North Atlantic, only near the beginning of the nineteenth century; and the habit spread slowly to other lands. For the past sixty years we have censuses, of varying value, for about half the population of the earth, and during the present century for nearly three-fourths. But for perhaps a quarter of the world's population we must still rely on estimates of uncertain and variable value. In very few countries can we find a firm basis for a study of changes over the last three generations. Hence there are practically no reliable studies of long-period population changes; and here I shall confine myself mainly to the facts of the present century.

At the beginning of this century Levasseur made a notable study of the distribution of the world's population, in which he calculated the proportions living in the various zones. This part of it I have reworked for the present day, and the results are shown in the following table (I), p. 116.

The chief conclusions which may be drawn, tentatively, from these figures are (1) that the proportion of mankind living in the intertropical lands has diminished, though this change may be only apparent, due to reduction in some of the estimates which Levasseur used; (2) that there has been a considerable increase in the small proportion which inhabits the south temperate lands, and (3) that the really populous zone of the northern lands has maintained, or even slightly increased, its dominance. The last column indicates that the density of population in the north temperate lands is three times as great as that in intertropical lands, and more than four times that in the 'new' countries of the southern hemisphere; though the latter have more than doubled their populations during the present century, with the greatest increase in Argentina.

But the tropics are very arbitrary dividing lines for any such study; and my only reason for using them is the fact that Levasseur did so thirty

1 For references see end of Address.
years ago and so they give a basis for a comparison. It is more useful to note the chief populous regions. These are clearly shown, as far as the scale allows, on the accompanying map (Fig. 1). Evidently there are only four regions in which the mean density of population considerably exceeds the world average of about forty persons per square mile, over

**Table I.**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Land area</th>
<th>Population (about 1907) (Levasseur)</th>
<th>Population (about 1936)</th>
<th>Mean density, persons per sq. mile, 1936</th>
</tr>
</thead>
<tbody>
<tr>
<td>North of the northern tropic</td>
<td>50.2</td>
<td>74</td>
<td>75</td>
<td>60</td>
</tr>
<tr>
<td>Between the tropics</td>
<td>40.5</td>
<td>24.3</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>South of the southern tropic</td>
<td>9.3</td>
<td>1.4</td>
<td>2.8</td>
<td>13</td>
</tr>
</tbody>
</table>

The uninhabited Polar Lands are not included.

any large continuous areas. I have estimated the extent of these regions, as continuously habitable lands, within boundaries drawn round their cultivable lands, and also the populations within those boundaries, and so obtained the figures given in the following table (II), from which it is seen that these four regions together contain about three-fourths of the world’s population on little more than one-eighth of its total land area.

**Table II.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Area, in millions of square miles</th>
<th>Population, in millions</th>
<th>Central latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Europe’</td>
<td>2.8</td>
<td>520</td>
<td>50° N.</td>
</tr>
<tr>
<td>Eastern North America</td>
<td>1.9</td>
<td>100</td>
<td>40° N.</td>
</tr>
<tr>
<td>The Far East</td>
<td>1.7</td>
<td>500 ?</td>
<td>35° N.</td>
</tr>
<tr>
<td>India, with Ceylon</td>
<td>1.0</td>
<td>350</td>
<td>25° N.</td>
</tr>
</tbody>
</table>
REFERENCE

per square kilometre  per square mile

1. Less than 1 person  Less than 2.5 persons
2. 1-15 persons  2.5-40
3. 15-75  40-200
4. over 75  over 200

Fig. 1.—World: Density of Population.

Note that the mean density for all the land is about 15 persons per km² (40 persons per sq. mile);
so that a — marks densities below the average.
b — marks densities above the average.
Elsewhere there are a few small areas of relatively dense population, as in Java, Malaya, and West Africa, but the greater part of the land is thinly occupied. Of particular interest is the belt of deserts which forms a zone across the Continent from the Sahara north-eastward to Eastern Siberia; for it was this 'Great Divide' of empty lands, interrupted only by few and generally small oases and occupied by widely scattered and generally nomadic peoples, which held apart the civilisations of the 'East' and the 'West' during all the ages of human history before da Gama's voyage to India in 1497 C.E.

In these great regions there has been only one change of world magnitude within recent centuries, namely the peopling of Eastern North America between 1620 and 1920, mainly in the last hundred years. This has added a fourth populous region capable of ranking with the three of the Old World; though it has not yet had time to accumulate so dense a population as any one of them.

Except for this the recent shifts of population have mainly been within the great populous regions, and have tended to accentuate their relative importance. The population of India has doubled its numbers since 1871; but the numbers of Indians settled outside India and Ceylon is only about three millions, or less than one per cent. of the Indian peoples, and less than one-sixtieth of the increase of the Indian population since 1871. And most of these are in Burma and Malaya.

The numbers, both absolute and relative, of the emigrants from the Far East are more difficult to determine. It has been estimated, by Prof. Mukerjee, that some ten million Chinese live outside the lands claimed by the Chinese Republic; half of whom are in Siam, Malaya and the East Indies. Similarly, there are perhaps two million Japanese outside their native land; but three-fifths of these are in Taiwan (Formosa), Chosen (Korea), Karafuto and Manchukwo, leaving less than three-quarters of a million outside the Far East. So the total population derived from the Far Eastern Region and now living outside it may be estimated at less than two per cent. of the home population. It is twice as numerous, both absolutely and relatively, as that from India; but, like that, it is a very small proportion of the probable increase in the Far East during the last two or three generations.

The really large-scale migration of the past hundred years was that from Europe to North America. But the number of all the peoples of European origin now living outside Europe and North America is probably less than a tenth of the number in those two continents, and not more than a third of the increase in the population of Europe itself during the past century. Yet Europeans form the great majority of the peoples of all the 'new' lands of the south temperate regions, except South Africa. Even if we count North America as a colony it is still true that little more than a fourth of the peoples of European origin live outside Europe, though the population of that continent has increased fourfold in the last two hundred years.

During the present century there have been extensions of the inhabited lands on the margins of all four of the major populous regions. In North America this has been a thrust westward and north-westward on the
E.—GEOGRAPHY

prairies which has reached, and perhaps overshot, the climatic limits of the region of good cultivable lands. India has made a real expansion on to newly irrigated lands in the Indus Valley. Chinese colonists, to the number of more than thirty millions, have pushed into Manchukuo and Inner Mongolia in the greatest of recent migrations. There has been a similar eastward colonisation from Russia into Western Siberia, in a belt near latitude 55° N. extending almost to Lake Baikal, which may now include twenty million people. But these are only expansions of parts of the populous regions, or in some cases possibly only outward oscillations of their margins; and they have not seriously altered the relative importance of those major regions with respect either to one another or to the rest of the world.

Thus the net effect of the great migrations of the nineteenth and twentieth centuries has been to add a fourth to the major populous regions, and then to increase the absolute and relative numbers of the peoples within these four major regions. They have not tended to spread population more evenly over the lands of the earth or to 'fill up the great open spaces,' but rather to accentuate the crowding of mankind into the already populous lands.\textsuperscript{2}

There has been a very great increase in the numbers of the human race during the last two hundred years. The European peoples have multiplied at least sixfold since 1700; and there is some reason to believe that both Chinese and Indians have at least trebled their numbers in the same period. The world's population is now about two thousand millions; and it probably did not reach five hundred millions at the beginning of the eighteenth century. But, always with the exception of North America, this increase has been mainly in the already populous Major Human Regions of 'Europe,' India and the Far East, which are the homelands of the three great civilisations; so that the relative predominance of these regions has rather increased than diminished. So far as the very scanty evidence for Africa goes, it indicates a decrease rather than an increase in the population of that continent, which is only just beginning to recover from the social disasters of the 'Slave Trade.' It is probable that the population of Spanish America declined in the sixteenth and seventeenth centuries. And it is only in the last sixty years that there has been any considerable increase in South America, mainly in the La Plata Region and in southern Brazil. Here the population has more than doubled since 1900; and the rates of increase in the early decades of this century are quite comparable to those of the United States in the latter half of last century. In the same decades Australia and New Zealand have had similar proportional increases. Nevertheless, the total population of all the lands of the south temperate zone has not yet reached fifty millions; and the area of good cultivable land in them is so much smaller than that of the great northern regions that they are never likely to be more than minor areas of world population. The figures in the following table (III), p. 120, calculated on the same bases as those in Table II, indicate the comparative importance of these south temperate habitable regions.

\textsuperscript{2} These conclusions agree with the views expressed by one of my distinguished predecessors in this chair, Sir Halford Mackinder, at the Centenary Meeting in 1931.
Within most of these population regions there are marked trends of internal migration. The most widely known of these is the so-called 'drift to the towns' which is associated with the steadily increasing growth, both absolutely and relatively to the total, of the urban population in all countries affected by modern Western Civilisation. This townward migration shows no signs of slackening, rather the opposite. In the last intercensal decade, 1921–31, the proportional increase in the London conurbation was more than double the rate for Great Britain, and that area absorbed half of the total increase of population of the country. Some other great conurbations grew even more rapidly, though none had a greater absolute increase.

This urban growth is mainly concentrated on the larger urban centres. At the beginning of the nineteenth century no conurbation in the world, with very doubtful exceptions in China, had reached a population of a million; though London was very near to that figure, with 954,000 inhabitants at the census of 1801. To-day there are in the world about sixty conurbations of this magnitude, perhaps a dozen of which have each as many as five million inhabitants, and together these include perhaps a twelfth of all mankind. The numbers, both of these 'million-cities' and of their inhabitants, are increasing; and if the trend continues unchecked for a generation or two our grandchildren may live in a world which will have a majority of its inhabitants housed in two or three hundred such conurbations.

The townward migration is associated with an absolute decrease of population in many rural areas, of which I need specify only a few instances. In Great Britain the decade 1921–31 saw an absolute decrease in every county of the highlands, and also a relative decrease in nearly all the counties bordering on the highlands. These areas of decrease included all Scotland, eleven of the twelve counties of Wales, and ten English counties. France records a corresponding decrease in the mountain departments of the Alps, the Massif Central, the Pyrenees and Corsica; as does Italy for all her mountain zones. In some of these areas the evidence of abandoned cultivation terraces is visible even to the casual observer. The same process of retreat from such 'regions of difficulty' is going on in all the mountain and highland areas of Central Europe and Scandinavia. There

<table>
<thead>
<tr>
<th>Region</th>
<th>Area, in millions of square miles.</th>
<th>Population, in millions.</th>
<th>Central latitude.</th>
</tr>
</thead>
<tbody>
<tr>
<td>'La Plata'</td>
<td>0.7</td>
<td>25</td>
<td>35° S.</td>
</tr>
<tr>
<td>Eastern South Africa</td>
<td>0.4</td>
<td>8</td>
<td>30° S.</td>
</tr>
<tr>
<td>South-eastern Australia and New Zealand</td>
<td>0.4</td>
<td>9</td>
<td>35° S.</td>
</tr>
</tbody>
</table>

Table III.
are apparent local exceptions, often due to the developments of tourism; though this industry maintains only a small, and often only a seasonal, local population, and it stimulates the exodus by increasing contacts with the outer world.

In some newer countries there is also a retreat of settlement from some thinly peopled areas. In the same decade, 1921–31, Australia saw a definite withdrawal of settlers from its inner areas of less than fifteen inches of rain towards the more humid regions nearer the coasts. And the still more recent exodus of ruined settlers from the semi-arid areas of the American 'dust-bowl' is more widely known. In these semi-arid regions it seems that close settlement had been pushed beyond its safe limits. The system of 'dry farming,' which had been widely introduced, involves the destruction of the natural vegetation cover and the loosening of the topsoil. Over-grazing has a similar effect because it compels the cattle to pull up and devour the stems and roots of the grasses. When this is followed by a more than usually dry season, accompanied by strong winds, the fine topsoil is blown away, and with it most of the plant-food. So both dry-farming and over-grazing are desert makers.

Such local retreats from unattractive areas are nothing new in the history of mankind. And it appears that there are more important general causes for the present trends of migration towards populous regions and great urban centres. Most of these seem to be results of the application of scientific knowledge to the work of the world. So that these great population shifts are essentially a result, and among the most important social results, of the developments of applied science.

First among these general causes I would put the diminution in the proportion of the world's workers who must be devoted to satisfying the primary needs of food, clothing and shelter, and to making the tools wherewith to do this. At the beginning of the Industrial Age more than half of all the working population of every country was directly engaged in the production of food, and of vegetable and animal raw materials, for most of their working life. Their manual power was supplemented by the labour of domestic animals and, to a small extent in some favoured regions, by clumsy wind- and/or water-mills. Now these industries have received a new equipment of immensely more efficient tools (compare the combined harvester with the sickle and the flail), of better and more productive seeds and animals, of more effective methods such as the rotation of crops, of better fertilisers, and of more efficient workers. As a result, their productive capacity has increased so that they can provide a much higher standard of material living for a greatly increased population. At the same time the proportion of the workers needed has fallen. It is now only some twenty per cent. of the total; and it seems likely to fall still further.

Similar changes have taken place in other primary industries. Such changes as the substitution of the steam-shovel and the excavator for the navvy's pick and spade, of concrete produced almost wholly by machines for the laboriously shaped stones of the quarryman and the mason, of the spindle for the spinning-wheel, have enormously reduced the amount of direct manual labour needed in many industries.
The first effect was to release labour for other purposes. And the industrial countries set out to equip themselves with new means of transport, roads and canals, ships and railways, and now motor vehicles and roads, with new buildings for industry and commerce and for the growing population. This led to, and was accompanied by, the development of the engineering industries; for engineering in all its branches is essentially the tool-making industry, and as such it may claim to be the fundamental industry of civilisation. Its development is the most immediate cause of the many economies of labour in other occupations.

A second effect was the enormous development of secondary industries, concerned no longer with the satisfaction of urgent primary needs; and a great amelioration of living conditions. Children have been taken out from the ranks of producing workers and sent to school. Leisure is more abundant and more widespread. Though it is clear that as a community we are still very far from having realised the full possibilities of the tools which science has put into our hands.

The food-producing industries were, and are, those which require their workers to be spread about the land. The agricultural workers, with their families and dependants, are the basis and the majority of the rural population. But the many workers released from these occupations could be grouped together; and the early developments of manufacturing industry, in respect to both the organisation of its labour and the use of machines and mechanical power, demanded such a grouping. So manufacturing industry is essentially an urban occupation, and industrialisation has everywhere been accompanied by urbanisation. However much its towns may be loosened out by the better use of improved transport, this urban character of an industrial population seems likely to persist; and so every increase in the numbers and importance of the secondary industries will contribute still further to the concentration of more and more of the people in and near to the great conurbations.

All these developments have been dependent on, and aided by, the rapid improvements in transport which have accompanied them. It is obvious, so obvious as to be usually forgotten, that no town can exist unless it can obtain adequate supplies of food, and that these must be transported to it from the rural areas in which foodstuffs are produced. It is equally true and obvious, that the maximum limit of any population is fixed by the amount of food available to maintain it. Hence I have regarded the conditions of the production of food as the primary determining facts in the numbers and distribution of mankind. The developments of transport since the early nineteenth century have made this dependence of urban on rural populations no longer local. But for the artificial and often arbitrary barriers interposed by human, mainly political, restrictions, the resources of the world might be regarded as a common pool for the supply of the needs of its inhabitants. And the developments of transport which justify this assertion have been so decisive that it is possible to express a large part of the problems and trends of population distribution in terms of transport.

Within the Major Human Regions which we have distinguished there are smaller areas of marked concentration of population. The United
States is the one great populous area in which freedom of movement has been at its maximum since the middle of last century; and the effects of this tendency towards further concentration are most clearly seen there (see Fig. 2). In a small area stretched along the coast and the 'fall line' from Boston to Washington, including both of these metropolitan districts, there were in 1930 about twenty-seven millions of people. Here then

![Fig. 2.—The Populous Region of 'Eastern North America.' Areas of maximum concentration are shown by the darker shading.](image)

there are more than a fifth of the population on about a hundredth part of the area of the country. There are other lesser areas of concentration, notably along the south shore of Lake Erie and round the south end of Lake Michigan; and Canada has one, stretching along the north shores of Lakes Erie and Ontario, with a greater relative concentration, for here thirty per cent. of the Dominion's people dwells on considerably less than one per cent. of its territory. But the three concentrations round the Lakes are together less than half as populous as the one on the Atlantic coast.
The correspondingly great area of concentration in Europe (see Fig. 3) is in two sections, separated from each other by the Strait of Dover. The British section stretches right across the island. Its north-western end includes the densely peopled urban areas of South Lancashire and West Yorkshire; its south-eastern part is the London conurbation with its satellite urban and suburban areas and its near coastal fringe of seaside towns; and between and connecting these are the almost equally densely
peopled industrial districts of the English midlands. This area, as it is shown on the accompanying map (Fig. 4), occupies a little less than one-

![Fig. 4.—The Area of Maximum Concentration of Population in Great Britain.](image)

fifth of the island. It now contains five conurbations each of which has more than a million inhabitants, and twenty other large towns with more than a hundred thousand each. Its mean population density is about
three thousand persons per square mile. The population in it, at various dates, is shown in the following table:

<table>
<thead>
<tr>
<th>Date of Census</th>
<th>1801</th>
<th>1851</th>
<th>1891</th>
<th>1921</th>
<th>1931</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population in millions</td>
<td>4.2</td>
<td>10.2</td>
<td>18.6</td>
<td>24.3</td>
<td>26.0</td>
</tr>
<tr>
<td>Percentage of the population of Great Britain</td>
<td>38</td>
<td>49</td>
<td>55</td>
<td>56</td>
<td>58</td>
</tr>
</tbody>
</table>

The continental section is a similar zone stretching from north France through Belgium to the Rhineland and the Netherlands. It may be noted that the three small countries which have each a large proportion of their area in this zone: England, Belgium and Holland, are the three most densely peopled lands of the world, each with more than one person per acre.

The European and the North American areas of maximum concentration are thus in comparable positions on the opposite shores of the North Atlantic, each at the chief ocean outlet of its region. The two chief conurbations, London and New York, are at present almost equal, each with about ten million inhabitants. In extent the two zones are also approximately equal; but the European area is the more densely peopled and each of its sections, British and Continental, has approximately as many people as the American area. Thus this area contains approximately a tenth of the whole population of Europe on a hundredth part of its area. And outside this great urban region, Europe has twenty million-cities, of which three (Paris, Berlin and Moscow) are approaching five million inhabitants each.

In the Far East there appears to be a recent development of a similar area of concentrated population along the lower Yangtze from Shanghai to some distance up-river beyond Nanking. In the absence of sufficiently exact census records and precise topographic maps it is not possible to state its area and population very definitely. But it seems to be fairly comparable in magnitude with the American and European areas, in both extent and population. Shanghai has about four million inhabitants and Nanking more than a million; while both cities have now ten times as many people as at the beginning of this century; so that they are growing more rapidly than any other comparably large cities of the northern hemisphere. Between them is a stretch of very densely peopled land with many large towns. In its position at the ocean outlet of a vast and populous hinterland the Chinese conurbation is fairly comparable to the American and the European; and given a stable government and peaceful development it may well rival them as a world focus.

Japan has two smaller areas of similar development. Round Tokyo
Bay there is an urban population of eight millions. Between two hundred and two hundred and fifty miles to the west, round Osaka Bay and in the valley inland from it to Lake Biwa, is a similar group of towns with a total of some six million inhabitants. The greater population of the Tokyo group is probably due to the fact that it contains the capital of the empire; for in most other respects the Osaka group, situated by the Inland Sea on the Yamato Lowland and much more central among the populous areas of Japan, has a better location. These great urban concentrations are largely due to the industrialisation of Japan; and, as very large conurbations, they are of recent growth. But they have no hinterland comparable to those of the great urban regions already discussed.

India shows no development of any principal area of grouped conurbations akin to those of the other three major populous regions. Its two 'million-cities,' Calcutta (or 'Hughlised') and Bombay, are far apart. They have developed first as seaports and later as industrial centres; but neither has any such pre-eminent advantages of geographical position as to become a focus of population comparable to London or New York or Shanghai. And India is still far less urbanised than the other correspondingly populous regions. Here the drift to the towns has hardly begun.

The motive determining all these migrations is, as always, the human desire for better conditions of life. Hence the trend is towards those areas which, in the circumstances of to-day, offer or are believed to offer the best opportunities. The applications of science to agriculture and other formerly rural occupations have diminished the need of these vital industries for large numbers of workers; and so released a large proportion for other occupations. Similar changes have concentrated the workers in other industries into large groups in urban areas. These changes, together with parallel developments in transport, have allowed the social instincts to find freer play—for man is a gregarious animal, and few of us really like to be isolated for any long time—and the results are seen in the growth, at an ever-increasing rate, of the greater conurbations and a corresponding decline in the population of many thinly peopled areas. If these social desires which make for crowding together continue unchanged, and the power to satisfy them continues to increase, the concentration of human beings into urban groups may become almost universal. Even the agricultural workers may dwell in towns and travel daily to and from their place of work over distances as great as those of some suburban journeys of to-day. But the grouping of industries round the great conurbations is more purely, though not entirely, due to economic factors; and so it is more readily capable of being modified by the action of Governments. The extent to which the growth is a recent fact may be seen if we recall that since 1900 Greater London (of the census) and Greater New York have each doubled their populations; whilst the Tokyo and Shanghai conurbations, with a later start, have increased about fourfold and tenfold respectively in the same period.

The trend towards urbanisation and concentration seems likely to be strengthened by the further, probable, increase in the productivity of agriculture; for if the amounts of food, and other agricultural products,
needed can be obtained from smaller areas the tendency to abandon the poorer marginal lands and concentrate cultivation in the more fertile areas will be greatly strengthened. These developments are occurring coincidently with the cessation of that rapid increase in numbers which has been a principal fact of human life for the past two centuries. Hence it seems that apart from catastrophic disturbances (such as a great war) present trends of population movements point towards (1) the probable reduction in the population of the, at present, thinly peopled lands, (2) a concentration of a still larger proportion of the world's inhabitants into a few great populous regions, and (3) a further increase in the size and dominance of a few areas of maximum concentration of population, among which the three leaders are those described in Western Europe, in Eastern North America, and in China.

References.

The chief bases for this paper are the census reports of many countries; Year Books of the League of Nations and some of the Dominions; such works as the Statesman's Year Book; and map studies.

Three works used for particular reference are:


MUKERJEE, R.: 'Migrant Asia.' Published at Rome (1936).

Previous papers by the writer on kindred topics which have been used in preparing this address include:

' Centres of World Power,' Sociological Review (1926).
' The Balance of Urban and Rural Populations,' Geography (1929).
' Millionaire Cities,' Mélanges de Géographie, Praha (1936).
' Whither Population?' Geography (1937).
SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

ECONOMIC RESEARCH AND INDUSTRIAL POLICY

ADDRESS BY
PROF. P. SARGANT FLORENCE,
PRESIDENT OF THE SECTION.

§ 1. CATEGORIES OF POLICY.

This Section of the British Association bears the title Economic Science and Statistics. I need not, therefore, apologise for confining the term economic research to inquiries that follow the ordinary scientific practice of generalising from observed facts, measured and summarised in the form of statistics. Such enquiries are often known as realistic, thereby casting, perhaps, undeserved aspersions on purely deductive theory. Be that as it may, my object in this paper is to review the conclusions reached by so-called realistic economists in recent years on the problems of practical industrial policy facing private business organisations as well as the State. These problems of industrial policy have become prominent first under the caption of 'rationalisation,' later under that of 'planning.' To-day, instead of being taken for granted or discussed behind the closed doors of Cabinet or Board Room, industrial policies are publicly reviewed and reconsidered in the heat of argument and often in the dangerous twilight of a little knowledge. Can economists not add to this knowledge and direct the argument less hotly perhaps but more to practical purposes?

The main purpose of industrial policy is, we assume, to promote economic efficiency, that is, to increase income, output or satisfaction at the least cost, monetary, physical or real.1 If this is not so, the non-economic purpose must be explicitly stated and not just assumed. What economists, as such, are interested in is not the purposes or ends but the means or policy. Of the policies advocated as a means to maximum efficiency, some are alternatives within the same category; others are in different, but supplementary, categories.

As I see it the main categories of industrial policy consist in problems of industrial structure; problems of industrial functioning or administration; and problems of industrial or economic technique such as price fixing or output restriction. These three sets of problems form

1 For elaboration of these three levels, to which the fundamental economic terms may be referred, see Florence, Economics and Human Behaviour, pp. 90–93.
categories in the sense that every industrial organisation must have some variety of structure, of administration, and of technique. This paper is mainly concerned with the category of structural policies. These fall, to follow my model, into three sub-categories which can be succinctly summed up as problems of site, size and scope. They form categories of structure, again, in the sense that every industrial structure must have some site, some size and some scope.

§ 2. The Industrial Site.

The problem of site has always exercised a business organisation whenever it planned to move or to open a new plant or branch. Recently the State has become interested in the siting or 'location' of industry through its policy of helping distressed areas by encouraging firms to 'site' new plants there, and the Commissioner for the Special Areas of England and Wales has gone as far as to suggest placing Greater London out of bounds for further factory construction, unless good reasons to the contrary were adduced. This policy, as the Commissioner points out, would involve the licensing of new factories and of extensions to old factories in the London area. This year a Royal Commission has been appointed to 'enquire into the causes which have influenced the present geographical distribution of the industrial population of Great Britain and the probable direction of any change in that distribution in the future; to consider what social, economic or strategical advantages arise from the concentration of industries or of the industrial population in large towns or in particular areas of the country; and to report what remedial measures, if any, should be taken in the national interest.'

The national value of a careful choice of the location of industry, a choice making full use of research, has nowhere been more precisely put than in the SecondIndustrial Survey of South Wales: 'The working of economic forces will eventually bankrupt any concerns which have made a wrong choice and will thus ensure for the community the optimum distribution of its resources, but only after an interval of confusion, and possibly after the creation of fresh pools of stagnant labour unable to find an outlet. A better choice made now would ensure the earlier attainment of the optimum location of resources, and would eliminate much confusion and waste. Though in form a wisely conceived State direction of location might appear to be an interference with the working of "natural" forces, it might in fact prove to have been only a short cut to the equilibrium which the free working of those forces would eventually ensure.'

In recent years considerable research has been devoted to this problem of siting or location of industry. Theoretical economists with the almost single exception of Alfred Weber have been content till recently to give the problem but a passing reference. Weber's Über den Standort der Industrien, however, suffers from the usual limitations of a deductive approach that its assumptions are unreal and its argument over-simplified. Examining the more recent theoretical contributions of Öhlin and Predöhl

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2 Third Report, p. 8.
3 Vol. I., p. 397.
as well as that of Weber, Mr. Dennison concludes that a review of the various theories of location shows quite clearly the lack of any concepts which can be used in dealing with actual problems.4 A particular mistake, in Mr. Dennison’s view, is that these economists dealt with industry as a category rather than with actual industries.

Thanks to accurate censuses of occupations and production it is now possible to inquire inductively into the location of actual, particular, industries. In 1929 I suggested a measure of the concentration of any particular industry in any given area by comparing the proportion of all occupied persons that were occupied in that industry in the given area with the corresponding proportion for the country as a whole.5 A similar result is obtained by comparing the proportion of all persons occupied in any particular industry found in the given area with the corresponding proportion for industry as a whole. Thus, 54·3 per cent. of all brassfounders in England and Wales were found in 1931 to be in the West Midlands area distinguished in the Census of Occupations, but the proportions of the occupied population in the West Midlands was only 11·5 per cent. for all industries. A measure of the concentration of the brass-founding industry in the West Midlands can thus be stated as $54.3 \div 11.5 = 4.7$. In a paper yet unpublished, read before Section F of the British Association last year, Mr. A. J. Wensley and I worked out this measure, which we called the location factor, for all the industries distinguished in the 1931 Census of Occupations in respect of each of the twelve areas or regions into which that Census divides England.

The fact that some particular industry is concentrated in some particular areas though important for the siting of individual businesses, is, for purposes of State policy, not so significant as the fact of the general diffusion everywhere or concentration anywhere of the given industry. If a depressed area is to be developed by the introduction of new factories it is essential for the State to know which are the industries whose units can be arbitrarily shifted. Some industries such as aerated waters are widely diffused wherever the population presents consumers, others such as cotton are narrowly concentrated where the skilled labour is found. But there is probably a middle grade of industries that need neither be completely diffused nor completely concentrated, some of whose units can, within limits, be sited anywhere without loss of efficiency. To discover which industries fall into such middle grades, Mr. Wensley and I worked out a measure of localisation based on the location factor.6 When an industry is evenly scattered over the whole country, the location factor already explained would clearly be unity for each region. To show in one figure to what degree each industry is localised we calculated the coefficient of localisation based on the mean deviation from unity of the industry’s regional location factors. Clearly a weighted mean deviation

is a better indication than an unweighted one, for a high or low location factor in a large area represents a greater degree of concentration or otherwise than the same factor in a small area. Weighting is particularly necessary where the official region is used as a basis since these regions range from Greater London with 21·8 per cent. of the occupied population of England and Wales to North Wales with 1·6 per cent. If the weight used be these percentages of occupied population, a short-cut device can be used avoiding the calculation of the regional location factors. This is not the place for the demonstration of this device; but a warning must be issued that, apart from methods of calculation, the coefficient is liable to be less significant the larger the areas used.7

The coefficient of localisation can vary from 0·00 for no localisation to 2·00 for extreme localisation. When the official regional areas are used as a basis, tin-plate shows the highest coefficient with 1·81. Lace, 1·68; cotton weaving 1·49; cotton carding and spinning 1·45; hosiery 1·45; cutlery 1·45; and pottery 1·44 are not far behind. At the other extreme are local government 0·05; dealing 0·12; mineral waters 0·13; bread and flour 0·15; and beer-breweries 0·22—all well distributed.

Industries in the middle ranges of the coefficient which offer the best hope of large development in the depressed areas include artificial silk spinning (coefficient 1·15), cocoa and chocolate (coefficient 0·86), mining machinery (coefficient 0·82), toys, games and sports requirements (coefficient 0·74), rubber (coefficient 0·70), biscuits (coefficient 0·64), electrical apparatus (coefficient 0·62), sugar confectionery (coefficient 0·53).8 The mere possession of a middling coefficient is of course not enough to cast the industry for development in a depressed area. Research must take account of the special circumstances of the area and the industry and must work on some theory of the reasons for location checked by statistical measures and itself checking those measures. Where the fuel, materials and markets of a particular industry are concentrated at distant places, for instance, theories such as Weber's as to their relative force in determining the most efficient site must be tested and checked by reference to the statistical factors and coefficients. If, as seems to be the case in England to-day, the forces that determined the present localisations are changing and the market is becoming more important at least than fuel, this should be shown by a halt in the progress of localisation and of the more localised industries. Areas seem to be depressed to-day largely because their industries were too self-centred and too far from the centre of the country's population. Delocalisation may soon be taking place in the sense that there will be a smaller proportion of men employed in an industry where that particular industry used to be localised. Realistic research in siting problems has not yet however proceeded much beyond

7 Mr. Wensley has worked out a 'truer' coefficient of localisation for a sample of industries based on a division of the country into very small localities. The differences in the case of the same industry between the truer localisation coefficients and the coefficient based on the official twelve regions of England and Wales did not, in practice, however, turn out to be great.

8 See The Second Industrial Survey of South Wales, Pt. III, chap. 3, for list of Suggested New Industries.
the stage of the exact yet summary measurements which may soon test such an hypothesis of delocalisation. But this is something achieved!

A statistical series, such as the location factors and the localisation coefficients of all the particular industries distinguished in the Census of Occupations or the Census of Production for different years, enables the economist to see exactly what is the situation or trend in situation that he is trying to explain. He cannot just use a few well-known locations and localisations as illustrations when it suits his argument, but must frame a theory which, as a working hypothesis, will explain all or at least the bulk of the measured observation in the series before him. It is to be hoped that this working out of standard measures of localisation will now permit a realistic understanding of the forces at work upon which to base effective siting policies.

So far the problem of site has been confined to the localisation of some particular industry with reference to the population as a whole. But the concentration of industry generally into a relatively confined geographical area is also exercising the State government, as the terms of reference of this year’s Royal Commission, mentioned earlier, clearly show.

It is the problem of urbanisation or, rather, suburbanisation. Just as the localisation of a particular industry presents (external) economies of supply of labour and auxiliary services specialised in that industry, so general localisation presents (external) economies of an accessible supply of general labour and services which, with the wider use of semi-skilled occupations, are not much less important. The scarcity and high rents of urban sites and new transit facilities, however, urge labour and factories to (not necessarily the same) suburbs. Hence the economic inefficiencies of ribbon development and of hours and expenses per man getting to and from work, and the strategical problems connected with population congestion in time of war. What is usually lumped by economists under the simple title of localisation thus appears to have four distinct meanings, all of them of separate importance in forming policy.

1. The location of a particular industry in a particular area: Measurable by the location factor of that area.

2. The concentration or localisation of a particular industry anywhere in the country. The degree of localisation, measurable by the localisation coefficient.

3. The location of industry in general in a particular ‘urban’ area. Measurable by density of occupied population in that area.9

4. The concentration or localisation of industry in general anywhere in the country. The degree of urbanisation measurable, e.g. by the proportion of the total occupied population in towns or districts over a certain population density.

Research into the location and localisation of industry in general has recently been undertaken in the United States by economists of the Wharton School of the University of Pennsylvania headed by Prof.

9 Contour lines linking places of equal density of population may be drawn over the map of any country; and cross-sections cut showing typical successions or cycles of city, suburban and rural areas. See Florence, Statistical Method in Economics and Political Science, p. 116.
Carter Goodrich. In a chapter of their *Migration and Economic Opportunity* entitled, 'The Changing Pattern of Industrial Location,' they divide the areas of the U.S.A. into seven types: (A) principal cities; (B) satellite cities; (C) industrial peripheries; (D) other cities of 100,000 population; (E) peripheries of 'D' cities; (F) important industrial counties; and (G) the rest. The proportion of all 'wage jobs' and of wage jobs in particular industries are then given for recent years according as they are situated or 'located' in each of the seven types of area. In the last thirty years the trend of American manufactures as a whole is found to have been away from large cities. In 1899 39·5 per cent. of all manufacturing wage jobs were in large cities; in 1933 only 33·1 per cent. The types of area that gained in jobs were the suburban industrial areas 'B' and 'C,' or 'G'—the country. Goodrich and associates also show what particular industries favour the different types of area. Steel-works, pottery banks, and worsted mills seem particularly to favour suburbia; flour-milling, clay products and woollen goods the country. Here, undoubtedly, a new line of economic research is opened up; the problem of the optimum urban-rural distribution of industry in general, and the most efficient incidence of particular industries in that pattern.

§3. The Size of Plants.

The problem of size arises continually in the policy of industrial organisations when they have to decide whether to take or refuse additional orders and how far, if at all, to extend and develop or, as in flour-milling and shipbuilding, to close down the works. It arises at irregular intervals in an acute form when there is some project of association or combination on foot. The State is now also taking a hand in size policy through its schemes of amalgamation of mines, of limitations by quota, closing down of redundant plant, and marketing boards for agriculture and coal. The bulk of the whole planning programme is in a sense a size policy. The size referred to is sometimes that of the technical factory and plant, sometimes that of the firm or combine or association that may control one or more plants. Has recent economic research discovered any rational basis for a policy either toward larger or smaller plants or firms?

Research into the problem of size of industrial organisations has proceeded further than into that of site. The stage of devising descriptive measurement has been passed and the grounds for supposing one size to be more efficient than another are being explored. To a certain degree mere description of the actual situation is a test of efficiency, since a given situation in sites or in sizes is the result of efficiency in survival from past policies; and efficiency is tested to a yet greater degree by the description of the trend of changes over a period of years. In comparing sizes of organisations, however, more direct tests have been adopted, such as costs and profits. The evidence of the actual distribution of sizes of plants, and trends in this distribution, will be considered first, beginning with manufacturing plants.

The actual distribution of sizes of factories, measured by men employed, is now at last obtainable for separate British industries in the
Census of Production for 1930. The situation is shown to be surprisingly similar to that already known for the United States of America, through its long series of decennial Censuses of Manufactures. Even when due allowance is made for differences of definition the average size of the British appears extraordinarily similar to that of the contemporary American factory. But the interest does not lie in average size for industry as a whole so much as in the typical differences between industries. These differences, again, seem extraordinarily similar in Great Britain and the United States, and indeed in Germany, too.

Some years ago, before the publication of the 1929 American and the 1930 British Census, I presented a table showing the distribution of the wage-earning population of the U.S.A. in 1909 among plants of eight ranges of size in fourteen leading manufacturing industries. I have now been able to draw up a similar table for the U.S.A. in 1929, for Great Britain in 1930, and Germany in 1925, adding three more industries, furniture, hosiery and chemicals that have since become equally leading. Only a brief summary can be given here, by presenting in a table the percentage of all employees that are found in plants of over 500 employees. As the footnotes to the table indicate, a certain caution must be used in comparing these percentages too literally as between different countries; yet the conclusion is justified from the general distribution of workers that in spite of difference in country, the same size of plant tends to prevail in the same industries. This conclusion would indicate that in determining size of factories there are technical or economic factors at work common to all industrialised countries, rather than factors particular to any one country. To be of use to policy research must discover these underlying factors.

At Birmingham we are now engaged in tracing the relation of size of plant with the degree of mechanisation. Mechanisation is difficult to measure directly, but some cross between horse-power and overhead costs per worker is perhaps the most sensitive index. Though it is easiest to obtain, horse-power per head fails to indicate the presence of many hand-operated machines, as in shoe-making, and must be supplemented by some measure of overhead costs. This is obtainable in the British Census by subtracting for each industry average earnings per operative from net output per head. Admittedly, overheads per head may measure other elements besides mechanisation, such as specialised salaried staff and marketing cost, yet the machine costs such as maintenance, repair, depreciation and obsolescence are probably predominant. On the whole the

10 Where he owns more than one factory it is officially left to the employer to decide whether to return the size of each single factory or the whole firm. Comparison with statistics of the distribution of sizes provided by H.M. Chief Inspector of Factories point to the size of single factories as that normally returned.
11 See Footnotes to the Table.
12 Logic of Industrial Organisation, Table II, p. 30. The reason for the choice of industries and for omitting 1919, is given in a footnote, p. 29.
13 Gas has been omitted from the original fourteen industries as being a public utility rather than private manufacture.
## TABLE OF COMPARATIVE SIZES OF PLANT.
Percentage of all Employees $^{15}$ in Plants employing over 500.

<table>
<thead>
<tr>
<th></th>
<th>U.S.A.</th>
<th>G. B.</th>
<th>Germany</th>
<th>Prevailing size of plant employing bulk of workers in the three countries.$^{18}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1909</td>
<td>1929</td>
<td>1930</td>
<td>1925</td>
</tr>
<tr>
<td>All Manufactures</td>
<td>28.0</td>
<td>37.7</td>
<td>38.3</td>
<td>33.6 $^{16}$</td>
</tr>
<tr>
<td>Foundry and General Engineering</td>
<td>26.1</td>
<td>28.0</td>
<td>49.7</td>
<td>42.2</td>
</tr>
<tr>
<td>Cotton Textiles</td>
<td>57.7</td>
<td>57.7</td>
<td>25.3</td>
<td>39.9</td>
</tr>
<tr>
<td>Printing and Publishing</td>
<td>8.6</td>
<td>14.3</td>
<td>31.6</td>
<td>16.2</td>
</tr>
<tr>
<td>Wool Textiles</td>
<td>47.2</td>
<td>43.7</td>
<td>35.7</td>
<td>32.9</td>
</tr>
<tr>
<td>Malt Liquor (Brewing)</td>
<td>14.4</td>
<td>—</td>
<td>36.2</td>
<td>15.0</td>
</tr>
<tr>
<td>Automobiles</td>
<td>52.5</td>
<td>86.3</td>
<td>71.2</td>
<td>66.5</td>
</tr>
<tr>
<td>Iron and Steel (Smelting and Rolling)</td>
<td>76.7</td>
<td>86.2</td>
<td>75.8</td>
<td>74.7</td>
</tr>
<tr>
<td>Car and Railway Works</td>
<td>57.4</td>
<td>59.3</td>
<td>67.3</td>
<td>73.5</td>
</tr>
<tr>
<td>Bakery</td>
<td>4.2</td>
<td>8.0</td>
<td>13.0</td>
<td>7.7</td>
</tr>
<tr>
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<td>68.6</td>
<td>73.9</td>
<td>61.2</td>
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<td>Boot and Shoe</td>
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<td>29.1</td>
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<td>1.2</td>
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<td>21.5</td>
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<td>15.8</td>
<td>8.4</td>
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<td>40.7</td>
<td>50.0</td>
<td>41.3</td>
<td>50.4</td>
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$^{15}$ Great Britain excludes from the Census all plants employing over 10 persons. For comparative purposes a similar subtraction has been made from the German results. The U.S. Census divides small plants into those employing 1–5 and those employing 6–20 wage-earners. Since exact calculation of the number employed in plants employing 1–10 is not therefore possible, no subtraction has been made. On a rough estimate these small plants employed in 1929 only about 6 per cent. of all employed in U.S. manufactures. Further, the U.S. Census measures size by number of wage-earners only, Germany and Great Britain by all persons employed. In 1929 U.S. salaried officers and employees numbered about 15½ per cent. of wage-earners. The U.S. percentages thus understate the importance of the large plants.

$^{16}$ Includes Mines and Building.

$^{17}$ Officially put out of existence by prohibition.

$^{18}$ Characterisation depends on knowledge of distribution of employees over all sizes of plant; and industries are not, of course, defined quite in the same way in each country.
facts in Britain, the U.S.A., and Germany seem to justify the generalisation that the higher the mechanisation of an industry, the larger is the size of its constituent plants or factories.

An explanation that may serve as a working hypothesis is that the more powerful and more costly the engines and equipment, the more it pays to congregate men round them in a single plant; also that mechanisation involves specialisation of processes and that the necessary co-ordinating of transport and communication costs arising from such specialisation are at a minimum when the specialists are all under one roof. In fact, most of the economic advantages of localisation can be seen at their optimum inside a single large works.

The particular index of size used—number of employees per plant—weighs against my generalisation as to the relation of size and mechanisation, since the actual process of mechanising involves employing fewer persons. That the more mechanised industries should on the whole be the larger-scale industries in the sense of containing plants employing the larger number of persons is therefore all the more significant. But there is one large group of factory industries forming an exception to this rule, those where the coefficient of localisation is low. An industry in this group may well consist typically of small plants and yet have a high horsepower and overhead cost per man. The explanation is not far to seek. Industries with a low coefficient of localisation are scattered among the population largely because of the high transport costs of a raw material that is scattered (e.g. timber for saw-milling or grain for grain-milling) or of a product required fairly universally by a population that is scattered (e.g. aerated waters or beer). Some of these industries are highly mechanised, but their plants cannot be large because production must be carried on in so many plants situated in scattered localities. Where the costs of transporting material or product are much greater than the economies of mechanised concentration, there a fortiori of plants will be scattered (i.e. unlocalised) and small. Among the costs of transport are liability to putrescence and need for communication between producer and consumer. It is these conditions that probably keep industries like furniture, baking, printing, and clothing small scale, i.e. small-plant, industries. Though close-to-consumer unlocalised industries are usually small-scale, it does not follow that highly localised industries are large-scale as some economists assume. Inductive investigation based on all the principal British industries shows that the highly localised industries, such as tin-plate, hosiery, cotton and wool textiles, pottery, cutlery, boots and shoes are predominantly medium-scale in size of plant.

Industrial policy requires that economic research look ahead so that the plans made to-day may not run counter to the forces of to-morrow. Is the large manufacturing plant likely to flourish under future conditions? Are industries likely to become large-scale yet?

20 This index is chosen as being free from the difficulty of comparing economic values between different countries and periods. Some of the difficulties in using this index to measure size are given in Florence, Statistical Methods in Economics and Political Science, pp. 154-155.
If the growth of large plants does not depend on localisation but, subject merely to a minimum degree of localisation, does depend upon the growth of mechanisation; then judging from the present rapid increase in mechanisation, the large plant is due to flourish, multiply and expand yet further. Measuring mechanisation only by horse-power per man it has increased steadily in U.S.A. manufactures from 1·25 h.p. per man in 1879 to 4·86 h.p. per man in 1929; in Germany from 0·82 h.p. per man in 1907 to 1·47 h.p. per man in 1925, and in British factories even in the short period between 1924 and 1930, from 2·02 to 2·44 h.p. per man. Many of the other elements in overheads per head can also be shown measurably to have grown. Not least important among them is the proportion of administrative and technical staff per operative worker. In British factories this was 11·7 per cent. in 1924, 13·5 per cent. in 1930.

The fact that an upward trend in size actually has taken place, whatever the underlying causes, can be seen directly in countries, which unlike Britain, have measured size in more censuses than one. My table shows that in America the proportion of workers in the larger plants (employing over 500) has between 1909 and 1929 risen from 28·0 per cent. to 37·7 per cent. for the total of manufactures and out of sixteen individual industries compared, has only fallen (and that but slightly) in the case of three industries. In German productive industry, between the Census of 1907 and 1925 the number of plants increased considerably less than the number of employees. Growth in size applied to all the groups of factory industries 22 except machine building and rubber.

What is the prevailing size of plant and the trend of size in industries other than manufacture? State policy is particularly concerned at present with the size of mining and may in the future, if some planners have their way, limit the number of retail shops by licence. Some countries are also threatening to proceed against the multiple chain store.

If the size of mines be measured like that of factories by men employed the prevailing size must be classed as large. The British (1930) Census of Production found 87·0 per cent. of miners in mines employing over 500 men. The corresponding proportion in Germany for 1925 was 82·9 per cent., and the trend here seems definitely towards larger mines, since between 1907 and 1925 the number of mines fell by 12·4 per cent. while the number of miners rose by 63·3 per cent.

The typical size of shop, on the other hand, is extremely small. It is calculated by Miss Douglas 23 from the British Occupation Census of 1931 that the average shop employs 1·4 salesmen and assistants to every 1 proprietor or manager. Assuming that there is a proprietor or manager to every shop this makes the average persons per shop 2·4. The corresponding figure for German retailing is 2·3 and for commerce as a whole 2·8. Nor does the trend appear upward. In German commerce as a whole between 1907 and 1925 plants increased by 63·7 per cent., persons occupied by 62·7 per cent.; and Dr. Ford has shown that for Great Britain between 1901 and 1931 the number of shops has increased, though in most trades not as fast as the population. 24

22 Statistik des Deutschen Reichs, Band 413, I, pp. 246.
Commercial establishments and shops in particular must by their very purpose be dispersed among the population and cannot be localised like manufactures. They must therefore be small. The dispersion among the population may, however, be too thorough in the sense that in any one neighbourhood there are more outlets for any one product than is necessary for the convenience of the neighbours, and that where deliveries are made errand boys continually criss-cross one another in their rounds. In England one shop to every 60 or 70 head of population has been the usual estimate, but the recently published trial census of distribution in six towns each of about 30,000 inhabitants, gives the observed frequency of 41.4 persons per selling-point or about one selling-point to every ten families.

Even if shops selling only the same wares are taken, this census shows that the population of 183,000 of the combined six towns was provided with 1,973 outlets for cigars, cigarettes and tobacco only, that is one outlet for every 93 persons, or say, twenty-two families; and with about 1,200 outlets for canned goods, for chocolate and sugar confectionery, for tea and coffee and for biscuits, that is one outlet for every 152 persons or, say, thirty-six families.

Is this typically very small size and small clientele of shops the result of a survival of the fittest? The evidence from costs and profits, to be taken in the next section in connection with distributive firms, shows that there is certainly no greater efficiency in the smaller shops. Rather the contrary. And the tale of bankruptcies, which is particularly sordid and tragic in the retailing trades, would go to suggest that the multitude of small shops is due to a continual trial and error process. Men without any experience or much capital are continually trying to set up as shopkeepers and almost as continually making an error. And the error involves the consumer as well as himself. If for lack of experience and capital a shopkeeper can only sell, say, £450 worth of goods he must charge a margin of 33 1⁄3 per cent. for his own gross profit in order to have a bare income of £150 a year. Thus, with a small total of sales a huge margin of profit (on sales) is quite compatible with a low (total) profit and forms a vicious circle, for the high margin keeps up high prices and checks sales further. With more sales per shop, however, a fair (total) profit is compatible with a low margin of profit (on sales); and a virtuous circle is engendered. The low margin of profit permits lower prices, these in turn stimulate more sales, and these in turn enable lower margins to be charged which in turn permit lower prices . . . ad infinitum.

§ 4. The Size of Firms.

The British and American censuses limit themselves to the size of plants, whereas State and private industrial policy is equally, if not more, concerned with the size of the firm or unit of control. Marketing and central selling schemes, for instance, whether in agriculture or mining, form an attempt to enlarge the business unit controlling several plants or mines rather than to enlarge any one plant or mine. The Government’s Economic Advisory Council reported in 1930 that in the cotton industry ‘the first essential step in the path of recovery’ was the formation of amalgamations large enough to secure economies of merchanting and finance rather than building larger mills or sheds. The policy of the
Rationalisation movement is to increase the areas under one planning and control authority irrespective of whether that area consists of one or a number of plants. And the policy of Planning, so-called, goes as far as to advocate that this area under one control shall be a whole industry. Nor must we forget that here in England we have in the last twenty years, seen the formation of a Big Five in banking, a Big Four in railways, and a Big One in chemicals—not to mention the policy of Bigs Limited in electrical engineering, soap, sugar, matches, cement and so on.

Economists have unfortunately not always been too clear as to whether they meant firm or plant when they were discussing scale of industry; sometimes they really meant neither. When they do quote statistics they are usually figures for size of plant irrelevant to the issue. For in discussing the trust problem or the newer problem of industrial leadership or the phenomena of monopoly, duopoly and oligopoly, it is size of firm that is relevant and in particular, the size of one, two or a few firms relative to the whole industry. And in discussing laws of increasing return it is, as we shall see, scope that is relevant—not size of organisation at all.

It is one of the advantages of a statistical approach that the inquirer must be quite certain what he is discussing. If he wants to know the number of persons in a unit he must, if he is to get a figure, specify whether it is the number in the plant that he wants or the number in the firm. Certainly, if the type of theory most relevant to this issue of size is to be 'checked' by statistics it is essential to distinguish firm and plant. The type of theoretical model I refer to is that of Mr. E. A. G. Robinson. In his *Structure of Competitive Industry*, Robinson breaks down the determinants of the optimum size of business unit into five forces: technical, managerial, financial, marketing, and risk. Finance and marketing, he thinks, usually demand a larger, management a smaller size. The size of an actual unit must therefore be a compromise. An industry requiring detailed management may very well have small *plants*, but the financing and marketing *firm* controlling several such plants can be large. Is this differentiation of plant and firm a real and common situation?

Here the German Census of 1925 is particularly helpful since it deals in separate volumes with plants (Niederlassungen) and firms (gewerbliche Unternehmungen). The distribution of workers among various sizes of organisation looks very different when the organisation referred to is a firm rather than a plant. In German productive industry generally there were in 1925 566,760 persons in large single *plants* employing over 5,000, but 1,442,039 persons in plants belonging to the large single *firms* employing over 5,000. In my table, 33·6 per cent. of all persons occupied in German productive industry are shown to be occupied in large *plants* employing over 500. The corresponding percentage for those occupied in large *firms* employing over 500 is 41·6 per cent. In commerce and transport the disparity between the numbers employed according to whether large scale refers to large plant or large firm is still more marked. There were only 23,620 persons in very large commercial and transport plants, e.g. shops and stations employing over 5,000, but, with the same

25 Subtracting those in plants employing ten or less.
numerical measure of very large, 1,263,109 persons in very large commercial and transport firms. In short, statistics collected by plants, to which America and Britain are mostly confined, seriously understate the degree of large-scaledness, if this is meant to refer to size of firms.

The reason for the difference in the typical size of plant and firm is of course that many firms have branch plants. The German Census of 1925 found that for industry and commerce as a whole, 42.4 per cent. of all persons occupied were occupied in firms with branch plants. There were, in fact, 45,634 firms with one branch over and above headquarters plant, 7,318 with two branch plants and 8,051 with three or more branch plants.

As to the trend in the size of firm, particularly these multiplant firms, no exact figures are available even for Germany; but the view is generally accepted that the combination movement is growing. Certainly, researches now being conducted at Birmingham into the largest British Joint Stock Companies, and also a random sample of all British industrial and commercial companies, disclose a much greater concentration of power into a few hands to-day than is usually supposed to be true for Great Britain. For any company to be a Holding or a Subsidiary Company and to possess Interlocking Directors in common with other companies is rather the rule than the exception. There is also the device, as yet little noticed in textbooks, of the weighted vote. A few special shares may be created with perhaps ten times the voting power of the ordinary 'ordinary' shares, thus helping an individual or a company that holds them to 'pyramid' control to astronomical proportions. For the moment we are not concerned with policies of internal control, but merely notice the wide and probably widening prevalence of large areas of control.

When, instead of prevalence and trends, profits and costs are used as measures of efficiency, it is of course the size of the firm that is being tested. The view of most theoretical economists has hitherto been that after a certain size is passed, in spite of marketing and financial economies and plant decentralisation, the firm becomes too large to be manageable. In so far as this view is at all based on statistical information, it derives mainly from the experience of the big trusts formed in America between 1893 and 1905 as summed up by Prof. Dewing writing in the Quarterly Journal of Economics for November 1921. Subsequent writers have not found the conclusion quite so obvious. Mead, following up Dewing's thirty-seven mergers, gives a table showing that during the years 1924–31, seventeen of the mergers averaged at least 6/ per cent. per year in dividend on the common stock, watered though it often was. Mead himself considers thirteen of these mergers, and one other that paid lower dividends, to have been conspicuously successful when accumulation of large surplus and provision for depreciation of plant and depletion of mineral properties is taken into account, in addition to payment of dividend.

More recently Livermore has taken a wider list of the mergers formed in America between 1890 and 1904. Out of 156 mergers that were important enough to have the power to influence conditions in their industry he found that 53 suffered early and 10 later failure, while 17

26 Corporation Finance, 7th ed., chap. XXXVIII.
limped along. But 76, or almost exactly half, were successes in the sense that they had maintained a high dividend between 1901 and 1932, compared with the average for their industry. Of these 76 Livermore counts 10 as rejuvenations and a further 10 as outstanding successes.

The mergers of 1890 to 1904 were mostly promoted on the expectation of monopoly profits. Their early experiences mark in Mead’s view the failure of an expected monopoly rather than the failure of large size. It is doubtful, in short, whether the theory of a low optimum management unit can find any factual basis in Dewing’s material. Nor must the suggestive inquiry of the American National Conference Board on *Mergers in Industry* be passed over. This showed that of the prices of sixty lines of manufacture in the period 1900–1925, those rose least, on the average, where consolidations had been strong in the industries producing them, while in industries not affected by the combination movement, prices rose most on the average. A possible explanation of this somewhat paradoxical result is that the monopoly profit which combinations are usually aiming at was obtained by reducing costs, and that to such an extent that prices could (monopoly) profitably also be reduced relatively to the no-combination industries.

Recently, two further original statistical inquiries have presented data on the relation of size of firms to profits. Both in Epstein’s *Industrial Profits in the United States* and in Paton’s *Corporate Profits as shown by Audit Reports*, it appears that the larger American Corporations made in the years 1924 and 1928 a lower rate of profit on their total capital than the smaller corporations. Neither of the authors are trying to present a case for the small corporation, but before their results are taken to heart in industrial policy a caution must be issued. Both authors when comparing sizes lump all industries together. But it is quite probable that different industries have characteristically different rates of profit on capital. Indeed, one of Epstein’s most valuable contributions is to show the permanence of differences in profit rates between different industries, at least over the period 1919–1928. Epstein himself is cautious on the interpretation, but industries requiring little fixed capital, or involving risk and uncertainty might be expected to have a higher rate of profit *per capital*. If, as I have given reasons for believing, large firms prevail in industries where there is greater mechanisation; and if, as is generally believed, smaller firms prevail in industries subject to wider uncertainties, it follows that small firms will tend to have the higher rate of profit.

In any case, Marshall’s warning 28 still holds that the supposed general tendency of the rate of profits to equality cannot be verified till economists agree as to what they mean by rate of profit and how to measure that rate. Marshall was doubtful whether profits should be rated merely on the basis of capital and suggested sales 29 or the wages bill as alternative or auxiliary

28 Book 6, chap. VIII, of his Principles.
29 May one hope that the Government will make or cause to have made further inquiries of the relative profitability *per ton of saleable coal* of undertakings of different sizes such as the Samuel Commission published in 1926? This showed for the first half-year of 1925 a definite tendency for the smaller undertakings to obtain less profit or suffer more loss than the larger firms. But more such evidence is required for more years and more of similar evidence for other industries.
denominators. Certainly, it cannot be assumed that for all industries there should be the same normal profit per capital on the books. State taxation policy abandoned this assumption under the Excess Profits Duty and, after a temporary lapse last spring, abandoned it again in the new National Defence Contribution. Thus, to be scientific, enquirers such as Epstein and Paton must isolate the comparison of profits per capital for different sizes of firms within single industries. Epstein gives data permitting others to make this isolated comparison. His conclusion that the smaller corporations are more profitable than the larger is based on an analysis of corporations whose average capital was $13,500,000. These corporations are not, unfortunately, broken down into size classes for specific industries. But a series of separate chapters give profit rates for particularly small corporations with an average capital of $171,000, and for twenty-three specific industries (excluding major and all miscellaneous groupings) the rate of profit of a sufficient number of these corporations is given to form a reliable average for the industry. Comparing this average for the small corporations with the average rate of profit for the large corporations as a whole industry by industry, the small corporations are found on the average for the five years 1924 to 1928 to have the higher profit in seven industries, the larger corporations the higher profit in sixteen industries.

Clearly, until the profit rates of different sizes of corporations within the whole larger-sized group is analysed industry by industry, it is rash to accept Epstein’s conclusion from his unanalysed group, that the smaller manufacturing corporations tend to be the more profitable. The very small corporation is probably not.

Rates of profit on capital even when compared within isolated industries are a difficult measure wherewith to interpret efficiency. Comparisons of costs as well as profits on output or sales are of greater direct use as a guide to policy, and economists must welcome the detailed cost analysis of distributive firms that are being published in America by the Federal Government and various Research Bureaus. One of the most remarkable results was found by the first (1930) U.S. Census of Distribution in averaging the operating costs of wholesale merchants of different size. As the size increased from firms selling under $25,000 a year right up to firms selling over $1,000,000, operating costs per $100 of sales fell continuously, for the nine successive classes of size, from $26.89 to $9.66.

In retail trade the outstanding cost and profit analysis are those conducted by the Harvard Bureau of Business Research. They certainly do

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30 The comparison is slightly biased in favour of the profitability of the small corporations by the fact that these did not include corporations suffering a deficit whereas the large corporations did. During the years 1922 to 1929 Epstein (op. cit. p. 350) does not consider this inclusion to be serious because of the relatively slight number and extent of such deficits.

31 Dairying, meat-packing, lumber manufacturing, blank paper, stationery castings and forgings, sheet metal.

32 Bakery, flour, confectionery, men’s clothing, knit goods (hosiery), furniture, cardboard boxes, newspapers, job-printing, paints, petroleum refining, ceramics, heating and ventilating machinery, electrical machinery, motor vehicles, tools.
not support the thesis of a limit to efficient size. McNair, in a review of the Harvard Bureau’s inquiries up to 1928, presents figures showing definitely a higher profit per sales for the larger department stores, lumber dealers, jewellers, grocers and shoe retailers. Since 1928 similar results have been repeated for department stores and have been newly established for specialty stores. This greater profit of the larger firms was due to their more economical purchase of merchandise rather than to their lower operating expense. Where chain stores are concerned it is often found that the larger the branch the lower is the operating cost, while the larger the whole firm or chain the lower the merchandise cost. A clear example is that of the chain groceries studied by the Harvard Bureau. As the whole chain gets larger the cost of merchandise falls. In chains of under nine branches the costs of purchasing the merchandise forms 81.9 per cent. of retail sales; in chains of ten to fifty branches it is 80.8 per cent.; in chains of over fifty branches it is down to 79.4 per cent. As the branch shop—the link of the chain—gets larger the operating costs fall. In firms with shops selling less than $50,000 a year on the average, expenses formed 19 per cent. of retail sales; for firms with shops selling on the average more than this expenses were down to 16.7 per cent. It is true that the purchasing cost of merchandise rises slightly for firms with larger shops and that operating costs rise slightly with larger chains, but this is not sufficient to offset the economies just mentioned, so that on balance the chains selling the greatest value of goods (whether by reason of large shops or a large number of shops) have the lower total of costs and higher profit per given amount of sales.

The U.S. Federal Trade Commission have recently investigated chain stores on a wider scale. Here the several trades covered show widely different results. Some trades, such as groceries, confectionery, men’s furnishings, men and women’s ready-to-wear, follow the Harvard grocery chain-store pattern. As the number of branches increases, merchandise cost falls considerably, operating costs rise slightly and, on balance, profits rise. On the other hand, variety stores either with a limit of $10 or no limit, department stores and dry goods, show a falling profit as the branches increase in number. It is noticeable that the nine trades where (according to the Trade Commission’s own table) profits per sales rise upward with increasing size of the chain, are trades with, on the whole, a higher rate of turnover or ‘stock-turn’ than the seven trades where profits fall downward with increasing size of chain. Only one of the nine upward profit trades has a turnover rate lower than 3.40; only one of the seven downward profit trades (department stores) has a turnover rate above 3.42. The rate of stock-turn is with certain qualifications a possible index, as we shall see, of the degree of standardisation.

It is possible that profitability depends not upon number of branches but upon standardisation and the reduction in the number of lines sold. Thus where the trade lends itself to a multiplication of lines it is rash for a firm to branch out, since not enough sales will be effected in each line to

34 *Harvard Bureau of Business Research Bulletins*, 83 and 84.
35 *Chain Stores: Sales, Costs and Profits of Retail Chains*, Table 34, p. 58.
justify the expenses of holding stocks. This possible source of inefficiency is essentially a problem of scope—the thesis being that a firm has widened the 'scope' of its transactions too far.

§ 5. The Industrial Scope.

An industrial plant may occupy a certain site and consist of a certain size, but the scope of its activities may yet be uncertain. The problem of scope is more familiar under the title of integration, if it is clearly understood that integration refers to any joint performance by one firm or plant of several separable transactions, whether this joint performance occurs by reason of combination of firms, through extension of a single firm's activities or always existed. The policy of industrial firms is constantly concerned with questions of scope or integration. Shall a new process be taken on to continue processes already performed; shall a new product be turned out from the materials already used for existing products or for the sake of a market already tapped; shall an auxiliary service be provided within the firm that is now purchased externally? These are questions in vertical, lateral and diagonal integration that an entrepreneur or Board of Directors constantly find themselves asking. Sometimes the question is in the opposite direction of disintegration, and the firm may decide on a policy of specialising in a comparatively few processes or services or a policy of standardising a comparatively few products. Policies of broadening or narrowing the scope of a firm may be quite independent of policies for increasing or decreasing its size. Employing the same number of men or producing the same value of goods a firm may reduce the number of its lines and, though not changing its size, may thus narrow its scope. Such a policy would increase the scale of production of the standard lines retained. It is this scale of production, not size of firm or plant, to which the economists' laws of increasing or diminishing returns refer; so that it is not till we consider scope that realistic inquiries link up with elementary economic theory. The terms some of us learned at Cambridge may now at long last be realistically employed. When an industry by reducing scope goes in for general standardisation and large-scale production of standard lines then external economies arise to increase returns. When a single firm or plant by reducing scope goes in for particular standardisation and what I have ventured to call large-scale operation of standard lines, then internal economies arise to increase returns. If only, alas, there were more realistic research into the truth of these hypotheses! The material, I believe, is there in the current records of British firms who have introduced mass, bulk, or batch production.

Now such a policy of narrowing scope is being widely adopted by British industry, and often constitutes the core of rationalisation schemes whether or not sponsored by the State. The Redditch needle trades have, for instance, adopted a narrowing of vertical scope so that each of a series of plants specialises in one process; the paper and, I believe,

the paint industry has adopted or proposed a lateral disintegration each plant specialising on a few varieties. Such schemes often combine a policy of increased size and scope for the firm or combine, together with diminished scope for the constituent plants. This seems the deliberate policy of Imperial Chemical Industries. The Economic Advisory Council advocated amalgamations in the Cotton Industry both to get spinning and weaving more closely related, and to secure the maximum economies from bulk production. Automatic machinery to be justified in any plant must, in their view, work ‘ upon a narrow range of products.’

Economists have become accustomed to the notion of an optimum size of firm or plant; a notion that implies a *pessimum* or rather a *pejus* size on either side, and rejects the idea that the minimum or the maximum is necessarily the most efficient size. Similarly we must get accustomed to an optimum scope or degree of integration for individual industries that is somewhere between minimum and maximum integration. But the problem remains, for research to solve, how to find this optimum of scope for any industry. There is an obstacle at the very outset in the difficulty of measuring scope by any one statistical index. The direct index would be the variety of lines produced or sold or, conversely, average number of units produced or sold in any given line or process. Unfortunately one line or process is inclined to merge into another and this proposed index would depend too much on arbitrary classifications. A less direct measure suggests itself in the rate of turnover of an industry’s, a firm’s or a plant’s output or sales, since the fewer the lines selected the faster they might be expected to sell relatively to stock-in-trade held. This is, in fact, one of the purposes of standardisation. The index may be accepted with the important reservation of fashionable and perishable goods. These are far from narrow in scope but to avoid obsolescence and putrescence they are sold fast enough.

Though the degree of integration or width of industrial scope is not easily measurable in figures, it is often possible to show graphically how one plant or firm has a wider or narrower scope than another. A series of superimposed charts on transparent paper can be adopted, like the *Popular Mannikins or Models of the Human Body* used by medical students. Where the technical processes of production, diverging from raw material or converging on the market, are fairly fixed, this may form, like models of the human skeleton, a common base upon which to superimpose, like charts of the nervous or muscular system, various patterns of integration. Thus, to take a simple case, petroleum is produced from oil wells, refined into petrol and other substances and then marketed. But these three vertical stages forming the fixed technical skeleton can be integrated into four patterns graphically shown by super-imposing enclosing circles. (1) Each stage by a separate organisation; (2) producing and refining integrated and enclosed in one circle; (3) refining and marketing integrated and enclosed in one circle; (4) all stages integrated and enclosed in one circle.

This may well seem rather elementary and childish, but I can assure you that when it comes to tackling the ramifications of the Birmingham
brass trades the alternative patterns of integration become positively kaleidoscopic and one is grateful for any elementary device to see it through. Indeed, the superimposed circles strikingly reveal how arbitrary is the notion of 'an' industry. One technical skeleton followed through vertically and laterally from head to tail and finger tip to finger tip, all raw materials to all finished products, may include dozens of industries. And what these industries are is determined largely by the usual course or scope of the enclosing circles, i.e. the policy of integration adopted in the past by the majority of plants or firms.

Sometimes these circles are firmly drawn and the great majority of firms and plants in one given industry keep within the circle and do not suffer trespassers; in other cases the frontier is not clearly fixed. The British Production Census of 1930 made, in its Final Report, a manful effort to measure how far firms assigned to an industry really specialised in the principal products characteristic of that industry. Two percentages are given for each industry, one showing the proportion of 'its' principal products included in the output of 'its' firms, the other showing the proportion of the output of its firms represented by its principal products. An industry whose firms made all of its principal products and nothing but those products, who were neither trespassed upon nor trespassing, would get 100 per cent. for each percentage. Such full marks for 'definition' were successfully attained on both counts by only six out of some 120 industries; grain-milling, ice, tobacco, matches, wall-paper and incandescent mantles. Markedly loose in definition are the industries of building materials, of fertiliser, disinfectant and glue, of tools and implements, of copper and brass, of finished brass, of coke and by-products, of oil and tallow and of manufactured stationery.

Once the different patterns and scopes of integration are defined between industries or within an industry, research may proceed to compare the prevalence, trends, cost and profits of each of them. Such a comparison of profits on capital investment has been made within the U.S. petroleum industry in the years 1922 to 1926. On the whole, the most profitable pattern appears to have been a division of the whole process into two 'scopes'; refining and marketing integrated (profits on capital varying year by year from 9.8 per cent. to 14.9 per cent.); producing isolated, with profits varying from 5.9 per cent. to 18.6 per cent. Complete integration with producing refining and marketing all in one scope showed profits only from 4.7 per cent. to 12.1 per cent. Refining isolated showed losses of 0.1 per cent. and 1.5 per cent. and profits of 5.5 per cent. to 13.5 per cent.

A chance for research into scope—under almost experimental conditions—is also offered wherever a given firm or a whole industry deliberately changes its policy. I have elsewhere collected several instances of particular standardisation, often effected with the help of branding and advertisement, with its results on cost and profit. One outstanding State experiment in general standardisation lies to hand in the 'Grid' policy of the Electricity Commissioners. There is some controversy

37 Recent Economic Changes, Vol. i., p. 194.
38 The Logic of Industrial Organisation, pp. 25-29.
about the comparative efficiency of large or small firms supplying current, but the policy of uniformity has, according to all competent observers, led to great savings in equipment by massing reserve capacity in central hands.


How far is economic research helpful to current industrial policy in determining the optimum, most efficient, site, size and scope of industrial organisations?

1. The first conclusion to be reached is that the methods of realistic economic research that try to check theory by observed fact are still in the imperfect tense. Index measures of size, scope and concentration of sites are being devised, tests of the efficiency of degrees of size, scope and site concentration are being worked out, and the conditions where various degrees of size, scope and site concentration may be found efficient are, very imperfectly, being discovered. But this research is, I believe, on helpful lines. It does take account of all the facts without assuming other things equal; it does necessitate a grasp of the real complexities of the industrial situation without inventing hypothetical cases; and it does aim at expressing its discoveries in specific terms and fairly exact measured degrees.

2. The discovery about industrial structure that is preliminary to all others is its diversity requiring, probably, diverse policies. Different industries have vastly different sorts of site, size of firms and plants, and scope. This diversity is also true within most industries; yet the summary measures devised by statistics show that individual industries usually have some prevailing sort of site, size and scope. Thus electrical engineering has predominantly large plants, associated with high mechanisation; pottery has predominantly medium-sized plants and high localisation; the ‘dealing’ or distributive trades small plants and low localisation. So many industries follow each of these three examples not only in Britain but also in America and Germany that it is permissible to speak of three types to each of which a common policy can perhaps be applied.

3. If tests of efficiency beyond the mere predominance or prevalence of a type be also consulted, it appears that in most manufacturing industries there is little sign of a limit to size of plant or firm, though there are signs that with the changing importance of the marketing and the production factors, the growth of localised industries may now halt. Some industries are absolutely dependent on local raw material or skill and are marked by a very high coefficient of localisation. But the policy of developing fairly localisable manufacturing industries away from their original sites may be justified as a short cut to a position that would be reached by economic forces anyway, but only after many and wasteful trials and errors. The newer site of the industry must not, of course, be just anywhere away from the old site. It should be carefully selected by research inter alia into the industry’s previous development there (measured by

the location factor of the area) and into the urban, suburban or country character of the place, for which also there are index measures. As to the efficiency limit of size in manufacturing plant, the prevailing size of plant in Great Britain, America or Germany is in many manufactures one employing over 500 men, and for nearly all manufactures the prevailing size is increasing. The typical association of this large size with mechanisation makes the policy of encouraging larger scale plants appear rational since mechanisation is increasing rapidly. But mechanisation does not appear to involve large plants where transport costs force plants, however mechanised, to be near a consumer market. In that case plants must be ubiquitous, numerous and therefore small. But even in these at present ubiquitous industries such as baking, brewing and furniture, reduction in transport costs \(^{41}\) may in the future permit of less ubiquity and therefore larger plants.

The extreme of ubiquity is found in the distributive trades. Here tests of efficiency fail to concur. Small scale shops and firms continue to prevail, yet their costs appear to be higher and their profits per given amount sold, lower than in larger units. In view of the general opinion about the rising costs of distribution and the widening middleman’s spread, further research as a basis of policy is here urgently needed. One must continue to deplore the apparent unwillingness of our Government to undertake a Census of Distribution such as the American, the Canadian, or the Irish. Before blaming Governments, however, perhaps we ought to confess that economists have not always made very clear what they wanted to get out of censuses nor made much use of them once they were completed!

4. The enlargement of the size of firms and combinations of firms so often involved in rationalisation and planning has often been opposed on the ground of the unwieldiness and the difficulty of any one brain managing large organisations. Statistical evidence that has been offered of lower profits among larger firms is, however, not easy to substantiate. The comparative efficiency of larger firms probably depends on what they do. If they enlarge by widening their scope and integrating either vertically or laterally they may reduce their scale of operation and thus get diminishing returns. If they enlarge by the increased production of given standard lines, they may secure increasing return. The manager’s brain is, after all, just one factor determining the curve of return. It may give way in attending to a thousand different varieties of integrated materials, processes and markets; but it may continue to flourish and obtain increasing returns if it can specialise in a large way. Much more research is wanted into the efficiency of different degrees of integration or scope within a firm (or plant) in any one industry. The optimum, most efficient, pattern may be specialised narrow-scope productive plants sited in selected places, controlled by a wide-scope integrated firm or combine which also does marketing and financing. But there is as yet little data to compare this, in efficiency, with other possible patterns, though I hope to have indicated by argument and examples the sort of data required for research into scope, and the methods of using that data.

\(^{41}\) See H. Levy, The New Industrial System, Part III.
The doings of a firm of given size and site do not stop short at variations in scope. Its efficiency will depend also, of course, on management policy—methods of staff appointment training and incentive, methods of sub-dividing function and delegating authority, methods of co-ordination of all these methods. Here also economic and quasi-political research may help—but that would require another address. To-day I must stop short at the category of structural policies.
Engineering started as an Art; at a later stage it developed into a somewhat scientific but purely empirical Practice; it is now the final stage of Applied Science.

That Engineering is a science has not always—and still in some quarters is not—recognised or appreciated, even among engineers themselves. For that we have no one to blame but ourselves. Too long were we content to act by the light of accumulated experience, not always fully assimilated. But Engineering has now for some time past realised that, without research, progress and improvement are impossible.

Engineers have sooner or later always made use of the discoveries of science; but the connection with science has been casual and haphazard. 'It seems exceedingly doubtful if Watt or any other inventor,' wrote Professor Lea, 'would have thought of the independent condenser, if it had not been for the fundamental work of a purely scientific character done by Toricelli, Boyle and others, on the pressure of the atmosphere, and that by Black and Watt which led to the discovery of the latent heat of fluids, and thus to a quantitative appreciation of the heat units involved in changing water into steam.'

But organised research was then something still unknown. For the first fifty years of its life the Royal Society had to bear the jeers and sneers of the pulpit, the platform, and the literary world. When Harvey published his tract describing the circulation of the blood it was received with ridicule, as the utterance of a crack-brained impostor, and he was deserted by almost all of his friends. This attitude of distrust on the part of the public lasted into the nineteenth century. But scientific research was at last becoming a matter not only for the individual crank and dilettante, but for scientific co-operation. The encouragement of research and the advancement of useful knowledge were indeed among the objects of the foundation of the Institution of Civil Engineers in 1818.

It may be interesting at this stage to remind ourselves very briefly of the history of research, and how very recent is its growth.

The Royal Commission, appointed to administer the surplus of £213,000 made by the Great Exhibition of 1851, used the money to purchase a large
piece of land in Kensington Gore, on which are built the South Kensington Museum, Schools of Science and Art, the Natural History Museum, the Museum of Scientific Instruments, and others that I need not mention. In addition to this many science scholarships have been provided.

From 1850 Government gave an annual grant of £1,000 (increased by £4,000 a year in 1877) to the Royal Society for the promotion of scientific enquiries, which went to aid research in mathematics, physics, astronomy, biology, chemistry and general purposes. The Society also benefited from many donations from its own Fellows. And from time to time private individuals, by donations or bequests, endowed fellowships.

But in Great Britain original research continued to be mainly the task of individual scientists, chiefly at their own expense. Industry had certainly not yet recognised its value, and it was to be a full generation before it was fully and practically accepted that scientific and industrial research is an essential factor in our industrial and national existence.

In Germany greater progress had been made. The lessons learnt in the Franco-Prussian War led to the institution in 1872 of the Reichsanstalt and the Materials Testing Department. The former was established in two divisions: the one devoted to pure science and the other to its application to the advancement of industry and manufacture. At the same time technical colleges for research and the training of research students were founded at Charlottenburg, Darmstadt and other centres. German industrialists quickly recognised the value of the work of these institutions. The A.E.G., Siemens and Halske and such great companies at an early date set up private research laboratories. The development of the dye industry is a perpetual warning and incitement, for it was Perkin who first discovered, in 1857, the manufacture of aniline blue; but it was left to the Dye Company of Germany to create from his discovery the great German dye industry, for which purpose huge sums were spent in developing new methods and evolving new dyes.

To return to our own country and engineering. In 1893 Sir William Anderson wrote: 'The days are past when an Engineer can acquit himself respectably by the aid of mother wit alone or of those constructive instincts, which in the past led our predecessors to such brilliant results.' Four years later the Government appointed a Committee under the chairmanship of Lord Rayleigh to consider and report upon the desirability of founding a National Physical Laboratory. The setting up of this committee was incidentally largely due to the agitation, led by Sir Oliver Lodge, at meetings of the British Association and elsewhere.

In 1898 Lord Rayleigh's committee issued its report, recommending that a public institution should be founded 'for the standardising and verifying of instruments, for testing materials and for the determination of physical constants,' and that it should be under the control of the Royal Society. The scheme was drawn up in 1899 and Dr. Glazebrook, F.R.S., (afterwards Sir Richard Glazebrook) was appointed its first Director, a position which he held until 1918.
The year 1900 is, too, an important dividing line in another sense. The National Physical Laboratory was founded just before it; and two years after it, 1902, the British Engineering Standards Association was established, by the co-operation of the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institute of Naval Architects, and the Iron and Steel Institute, under the chairmanship of Sir John Wolfe Barry, the great civil engineer. Since 1900 research has been on the whole, recognised as a question of national importance.

The history of the National Physical Laboratory has been one of continual expansion. From Kew it removed immediately to Teddington to have greater space. In 1901 the Engineering Laboratory was completed. In quick succession followed departments dealing with Electrotechnics, Electrical Standards, Optics, Thermometry, Pyrometry, Tide-Predicting, Road Materials, Physics, Metallurgy, Aeronautics, Ship Model Testing, to mention only a few of its manifold activities. By 1918 when it became part of the larger organisation known as the Department of Scientific and Industrial Research, it had already an expert staff of 600. It has now over 1,900.

The original committee of eight, under the chairmanship of Sir John Wolfe Barry, that controlled the British Engineering Standards Association, has now expanded into a body of 870 committees with 4,850 members.

In later years, co-ordination has become recognised as essential. 'In any earlier age,' said Mr. Thomas Midgley, on the occasion of the award to him this year of the Perkin Medal of the Society of Chemical Industry, 'when science and industry were simple individualistic processes, it is conceivable that some person, by his efforts alone, could have advanced applied chemistry to have justified your Committee to bestow upon him the Perkin Medal. To-day this is no longer so. To advance applied chemistry even a little requires the organised efforts of many individuals. Since you have chosen me as the recipient of the Perkin Medal for 1937 it is only fitting that I acknowledge at this time the aid which I have received from others in solving the two problems for which you are rewarding me.' Such ascription of merit would have to be made by every research worker of to-day.

The same is true generally in industry and manufacture. Every important industry and many manufacturers devote considerable expenditure to research. It is in fact the only means of continuous progress in an increasingly competitive world. It is almost the exception now to find a firm of any standing that has not its research department, and some of the most extensive and elaborate laboratories in the country are under the control of great manufacturing firms. The modern State is founded on scientific research—not like the French judge in 1794, who, in sentencing to death Lavoisier, one of the founders of modern chemistry, said that the Republic has no need of scientists!

Nowadays a vast amount of State-aided research is being carried out by State Departments, private Research Laboratories, Research Associations,
Scientific Institutions, Universities and Technical Colleges, and still by private individuals.

The engineering world has not kept pace with the scientific world; and it has been fortunate that the two distinguished directors who administered the activities of the National Physical Laboratory for the first thirty years of its existence, Sir Richard Glazebrook and Sir Joseph Petavel, should have been men of the widest views. Before 1914 the work of the National Physical Laboratory was very valuable, but during the War, it became indispensable both to Government and to industry. In due course it was found that a wider organisation was wanted to link in a more definite way the relation between science and engineering research and industry. A Joint Board of Scientific Societies formed a deputation under the leadership of Sir Joseph J. Thomson to stress the importance and urgency of the question on the Government.

The outcome was the establishment, in 1915, of the Department of Scientific and Industrial Research, under the control of a Committee of the Privy Council, with an Advisory Council of scientific men of the highest rank in the country; and in 1918 the National Physical Laboratory became part of the newly created department, though the Royal Society continued to control its scientific activities.

A glance at the summary of the latest report of the Department of Scientific and Industrial Research affords some idea of the immense engineering field it now covers in its work. It includes fuel research, food investigation, building research, steel structures, roads, road tar, forest products research, researches on water pollution, metallurgy, and radio, chemical research, illumination, lubrication, atmospheric pollution, furnace design, industrial respirators, radium beam therapy, X-ray analysis, and I may add, almost any problem you may like to put before them.

But apart from the immense importance of the scientific work done, the Department is the focus for linking together all the research going on in the country. This it made from the outset one of its primary objects; and one of the chief ways in which it accomplishes this, is by the encouragement of the formation of Research Associations. These associations are self-governing bodies formed on a national basis in various industries for research in the interest of the industries they serve. Each association is, or aims at being, a co-operative unit representing all the firms who belong to that particular industry. There is no fixed subscription, it being based on the size of each firm, so that for a very small sum a small firm may have the benefits of an organisation which is spending thousands of pounds annually on fundamental research of interest to the whole industry. The Associations work in close contact with the Department of Scientific and Industrial Research, to which each one submits a yearly report of the work it has done and the problems which it is studying. The Department’s help does not, however, stop at this point. In addition to advice and technical help, it contributes to the funds of the research associations by making a £1 for £1 addition for every sum provided by the members.
Of equal importance is the work carried on in the various research bodies under the management of the great scientific institutions. These again are largely co-operative in their aim. Some, indeed, as for instance the Research and Standardisation Committee of the Institution of Automobile Engineers, are affiliated to the Department of Scientific and Industrial Research as Research Associations, and receive the Department’s £1 for £1 contribution to their funds.

Nearly all the Universities now have research departments, which not only carry out practical work of importance, but also act as training centres for students who are to make research work their livelihood; while as already mentioned private research laboratories are maintained by the more important and wealthier firms—as well as by quite humble businesses. Their primary object is naturally the furthering of private interests, but they are not entirely isolated units. Many such research departments belong to one or other of the Research Associations and frequently pass on problems of a fundamental nature to them to deal with. All can work in contact and correspondence with the Department of Scientific and Industrial Research—if they desire.

I have tried to indicate the rise, growth, and present state of research in this country. Some idea of the recency of its growth may be gained from the fact that in the eleventh edition of the *Encyclopaedia Britannica*, published in 1910, the subject receives rather less than half a paragraph.

The early years of the twentieth century saw on the whole much greater research activity abroad and in America than here. It is quite impossible to enter on any account of these, but I might mention that the National Academy of Sciences, was founded in the U.S.A. as early as 1863, to deal with all phases of national research; and its influence in the United States is comparable to that of the Royal Society in our own country. In 1916 the Academy created the National Research Council to assist Government in organising the scientific resources of the country, which proved of such great service during the period of the Great War that it was decided to maintain it as a permanent organisation. One of its main branches was that of Engineering and Industrial Research.

The first years of the new century, also as with us, saw the setting up of the National Bureau of Standards by the United States Government, which covers an immense field and whose technical bulletins and other publications are the means of making widely known many of the latest scientific discoveries. America has indeed always been forward in promoting international standardisation in engineering and co-operation in research work, considering that the two matters must run together—as is so. The Bureau of Standards includes as part of its organisation a close co-operation with the research department of the Universities and other institutions in every State.

In America, too, industry and manufacture have taken a leading part in the research movement, and some of their great laboratories eclipse our own in size. The United States have developed a form of co-operative research of their own, of which the Mellon Institute is the best
known example, founded in 1913 by the brothers Richard and Andrew Mellon. Since its origin 1,150 research fellowships have been established in 275 technological subjects and 650 processes or products have been invented or developed. In ten instances new industries have resulted.

In Canada, where I was very recently, I was greatly struck by the action the Dominion Government is taking in the promotion of research. The National Research Council, with headquarters at Ottawa, where it has a magnificent new building, is not only carrying out a very wide programme of practical research, but is aiming at training a big body of research-minded engineers and scientists.

One could continue the story of research abroad, but I must stop. I have omitted much that those acquainted with the subject would have expected to be included. But I have done enough to show what a great deal has been done to establish research in our generation.

There is no finality. Every day extends the bounds of knowledge. We have only just begun to understand how to conduct organised research. 'The historian of the future,' writes Lord Rutherford, in the last Report of the Department of Scientific and Industrial Research, 'will probably point to the last five years as a period marking an important development in the industrial outlook of this country. These years have witnessed the fruition of the policy adopted by several large industrial undertakings of setting well-balanced teams of research workers, including chemists, physicists, engineers and where necessary biologists, to solve a particular problem or to develop a new product. This method of attack has led to the steady improvement of the efficiency of electric lamps, to the position this country has won in high definition television, to the development on a commercial scale of the huge plant for the conversion of coal into oil by hydrogenation, to the growth of the plastics industry and to many other important advances. . . . Co-operation can never win its fullest success until the contacts between men of ideas in industry and men of ideas in science are as closely knit as possible.'

Although I have dealt so briefly with the subject I hope I have made evident that research divides itself into several categories. It is, I think, very necessary to bear this in mind.

There is what one may call true fundamental research—splitting the atom, or extreme low temperature investigation. No one can doubt that the results will ultimately have their effect on human life. No one, however, can now say who will be benefited, or how. Such work must always be expensive, it must depend on endowments and generous gifts. It is not with this type of research that Engineering is directly concerned.

I am concerned with applied research, and it has its divisions. We have in the first instance work of more or less universal application—such as agricultural research, the breeding of new wheats, or methods of storage of fresh fruits; or investigations in regard to river pollution. The results once attained become immediately available to all the world. Such work too depends on endowments and Government support. This type of
research, as fundamental research, often finds its home in our Universities, and where there is still opportunity of individualism.

Then there is the research that deals wholly with the problems of a particular industry—aircraft building, or the development of welding. Here the whole work has a much more restricted field and definite goal. New truths are not sought; but the means of turning the inventions of others to practical use and the economic solutions of the problems of those concerned in the particular industry whatever it may be. The results can be more or less restricted to the members of the industry that support the research; and the admitted object is to benefit those members.

The Mellon Institute in U.S. typifies a rather different type of co-ordinated research. The Institute has a limited membership. Only one representative of each class of interest is admitted. For instance there is only one yeast firm that is a member. No other would be able to become a member. But of course the boundaries of the interests of many member firms necessarily overlap. The result is that while applied research is being carried on in many different fields in the Mellon Institute, all the members may benefit sooner or later from researches into problems not directly connected with them. The Institute is extremely ably run. The results have been considerable, and private research is enabled to be carried out on a broader basis than would otherwise be possible.

Finally there is the private research department, large or small, of every progressive company. Here while the results can be kept entirely confidential, obviously the scope is in some ways more restricted. Most companies find it necessary to pool inventions, and even so where research is carried on more or less in secret, there is danger that errors of approach may not be realised, until much damage has been done or time lost.

With these remarks, I turn to the all important question of finance. Research is expensive. Who is to pay? In the early days of discovery it was inevitably at the expense of the individual, and in this way many private fortunes were spent for the ultimate good of industry and humanity.

In the nineteenth century, apart from the scientists who spent their private fortunes, research was largely dependent on the endowment of public-spirited benefactors, and to scientific societies. Government, as I have already said, more far-seeing than the general public and in spite of futile criticism, began to aid in a small way from the middle of the century onwards. Generally speaking industry had not realised the importance of research and its attitude was almost hostile until the twentieth century was well on its way. The £54,000 raised for the Ramsey Memorial Fellowships, after his death in 1916; Sir Alfred Yarrow’s £100,000 in 1923, are earlier examples of the efforts of individuals which have their modern counterparts in Lord Austin’s and Lord Nuffield’s gifts to Oxford and Cambridge Universities.

But it is now sufficiently admitted that research should be paid for by those who benefit by it—the community and industry. The attitude of industry has changed from indifference to support. 'It is not easy to
assess over a period of twelve months the change that is taking place,’ writes Lord Rutherford in the Report I have already quoted. ‘Comparison of the attitude of to-day with that of ten years ago indicates more definitely what is happening. In one field of our work industry affords each year, clear and tangible evidence, that the forward movement which it has been our aim to encourage is gathering momentum. The steady increase in the total sum which industry as a whole provides annually for the development of Research Associations gives us good reasons for taking an optimistic point of view.’

In the year 1932-33 a total sum of £167,370 was supplied by all the industries concerned for the support of the Research Associations organised by them. In 1935-36 the figure had grown to £232,468; an increase of 40 per cent. in three years. But even so the position is not yet satisfactory, and industry still lags behind in its support of these Associations, in spite of the liberal encouragement of Government. I have no doubt, however, that this stage of affairs will not last. In the past year several important steps forward have for instance been taken, the opening of the splendid new laboratories of the Printing and Allied Trades Association, the Perivale Laboratories of the Electrical Research Association, the new laboratories of the Research and Standardisation Committee of the Institution of Automobile Engineers, the extensions to the Shirley Institute and the Research Station of the Paint Research Association at Teddington.

We have been experiencing a revival, and hopes are high again. This always makes it easier to get money. Unfortunately, when industry is depressed, and when research is all the more necessary, the necessary support is not forthcoming. I might instance the William Froude Laboratory. The work of the Institution was made possible by the benefactions of two leading members of the ship-building industry, Sir Alfred Yarrow in its early days, and Sir James Lithgow in its more recent developments. The maintenance of the research work, however, depends largely upon the provision of funds by the shipping and shipbuilding industries. Actually, the major portion of the expenditure has been met by payments for tests by individual members, while the industry as a whole has contributed only about £2,000 a year, an inadequate sum to deal with the immense field that has to be covered. In the years 1935-6, 73 ship designs involving the making and testing of 160 model hulls were dealt with. Four of the designs were improved in hull and propeller by more than 20 per cent., and effective improvements were made in 54 out of the 73 designs. ‘It has been calculated,’ we are told, ‘that if only one ship were built to each of the improved designs resulting from one year’s work at the Tank, the annual saving in the cost of operating the vessels would be more than enough to cover the cost of running the William Froude Laboratory for a year.’

Of course, here as always in research, it is the case that the greater the success of research, the more immediate and drastic the effect on existing plant and equipment. That is where the rub sometimes lies. Millions are necessarily sunk in fixed assets, which may in a year or two be made obsolete
by the development of new methods. Obsolescence is indeed so rapid nowadays, that it is not unusual for new plant to be written off in four years; and many valuable inventions have been bought up by vested interests and suppressed in order to save the greater loss that their exploitation would involve to already operating plant. It is therefore not surprising that there is not always an enthusiasm for unrestricted research or a readiness to praise it. But it is a shortsighted policy.

I have glanced at the rise and growth of the modern research movement. Co-ordination and co-operation have done much to link together the various elements, but there has as yet been no general national plan. For totalitarian states such things are not so difficult; but for that reason democratic countries too must organise and co-operate more closely than ever before. Groups of unrelated, often competitive, bodies cannot be really effective. In my opinion the time must come when every research organisation will be linked by some form of affiliation to a central controlling body. This would become inevitable in time if only to prevent hopeless overlapping and duplication, with attendant waste of energy, time and money. There is another direction where centralisation is equally necessary. I refer to publication. At present if the results of research are not kept as trade secrets, they are often broadcast in such a multitude of journals, books, papers, addresses, etc., that it is almost impossible for one who is studying any particular branch to avoid unwittingly covering ground already covered by previous workers. We have all experienced the difficulty of trying to collect all the latest information on the subject we have been called upon to deal with. I believe that approximately thirty thousand scientific periodicals are published throughout the world, each of which no doubt may contain the results of research in some form or other. In our own country no definite and practical scheme has yet been conceived for making available the results of research. There should, moreover, be some type of clearing-house of engineering information, such as would collect, collate and make immediately available all new data discovered. Some partial success has been attained in this direction in more than one way. The Executive Council of Imperial Agricultural Bureaux, for instance, an autonomous authority that deals with the finance and administration of ten scientific bureaux, works in close touch not only with all the councils but with other research centres such as the Low Temperature Research Station at Cambridge, the Building Research Station at Watford, and so on. If it be impossible even to work out a similar organisation for engineering on a national or world-wide basis, it cannot be impossible to establish at least a clearing-house system at a relatively small expense in co-operation with the Department of Scientific and Industrial Research. This Department, with the research associations which it partly finances, and others with which it is associated provides the ideal nucleus for such an information service, but Engineering must work out its own scheme.

I am afraid I have no definite proposals to make—at least at this juncture. All I have desired to do is to ventilate a subject of paramount importance
to engineering. I would thank you for so courteously listening to me; there is no more useful work that the British Association does, than offer opportunities for the ventilating of the vital problems and questions of the day. I am satisfied that at the moment in the engineering world—which after all means in the whole commonwealth—there are two outstanding questions, the co-ordination of effort and the promotion of intensive research.
SECTION H.—ANTHROPOLOGY.

ASSAM ORIGINS IN RELATION TO OCEANIA

ADDRESS BY
PROF. J. H. HUTTON, C.I.E.,
PRESIDENT OF THE SECTION.

In choosing this subject I am not attempting to offer any definite solution to the problems of Indonesian migrations, but propose rather to examine one aspect of them in the hopes that I may elicit further information from various quarters which may contribute towards the ultimate solution of what is really a complex of very difficult problems, as I feel that although a clearing up of the main question may be very distant some analysis of the Assam side of the problem is perhaps possible.

Many parallels are to be found of one sort or another between Assam and Oceania, some of which were pointed out by Sir Henry Yule and by S. E. Peal in articles in the *Journal of the Anthropological Institute* in February 1880 and 1893 respectively, and others of which I myself pointed out in an article on *Assam and the Pacific* in *Man in India* in 1924. In 1925 Mr. Henry Balfour pointed out cultural connections between Assam and Indonesia in the matter of certain types of thorn-lined fish traps and, more recently, of fretted horn and shell ear ornaments. It will, therefore, be enough here to demonstrate by three examples the general association between Assam and Oceanic cultures.

Evans has pointed out how the Malay word *buni* connects with the word ‘taboo’ throughout the Pacific, *buni* or *puni* having always some sense of segregation and a cutting off of communication with the outside world. This word *puni* clearly appears in the Naga words *penna* and *pini*, the Angami and Sema words respectively for the taboo observed by a whole village when intercourse with all strangers is entirely prohibited, and to the Pacific examples given by Evans might be added the use in the Marquesas of the words *penant* and *pana-le*.

The second example is that of the use of wooden images to accommodate the souls of the departed, whose skull is used to form part of the image. In the Naga hills certain remote Konyak villages across the frontier, e.g. Tobu, accommodate the souls of their dead in basket-work figures

1 Peal, S. E., 1893, *J.A.I.*, 22, 244 sqq.
3 Evans, 1920, *Man*, 38; cf. Hutton I, 192, 200 seqq.; II, 220. (*Note:* A key to roman figures used in references will be found in an alphabetical list of authorities at the end of the address).
5 Hutton, X.
the heads of which consist of hollow wicker cases into which the skull is put. Their neighbours, e.g. Angfang, carve on to the wooden statue complete with head two projecting horns to hold the skull in place. In neither case does the skull, however, form a permanent part of the soul figure as it does in New Guinea, where at Ron (or Run) soul images are reported, the heads of which are made with the skulls of the deceased. But an intermediate link appears to be found in the Nicobar Islands, where to a deceased person a wooden image is set up which has a cupboard in the back into which the bones are put and two horns or a sort of cup, in this case arising out of the neck, to form a receptacle for the dead man's skull. A third link is supplied by the Khasia hills in Assam, where the War of Shella erect a wooden post to accommodate the bones of the dead man, which are placed in the post symbolically by means of a cowrie used to represent what is left of his bones after cremation. Another link is probably to be found in the Borneo practice of interring the person's bones in a post.

The third example I offer is that of the associations of the hornbill with head hunting. This is well known in Assam and there is no need for me to go into details here, except to say that the tail feathers of *Dichoceros bicornis* are used by all Naga tribes as insignia of successful head-hunters, while the head of the same bird is worn at the back of the neck by men of the Lhota Naga tribe who have set up a menhir, and its split mandibles serve as 'horns' with the same significance as the feather for some tribes on their cane helmets as for the Angami on their breast ornaments. The feathers and head of *Aceros nepalensis* and *Rhytidoceros undulatus* are sometimes used as a substitute when those of *dichoceros* cannot be obtained.

For parallels in Borneo and New Guinea I am indebted to Dr. Haddon. The white-crested hornbill (*Berenicornis comatus*) is looked for as an omen on the warpath by Kayans, who wear hornbill feathers and, like several Naga tribes, tattoo their hands or arms as insignia of head-taking; *Bucceros* is similarly regarded as a good omen in Humboldt Bay in New Guinea and the wearing of its upper mandible in the hair is a sign that the wearer has taken human life elsewhere in New Guinea. Williams, writing of Orokaiva society in 1930, says that the hornbill's corrugated beak was apparently used as an emblem of homicide in former times and concludes that hornbill beaks and heads were exclusive homicidal insignia in British New Guinea.

It will, however, probably be safer to examine limited areas more closely for the existence of groups of parallels between Assam and Oceania.

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6 Frazer, I, 311, 324, quoting F. S. A. le Clercq and J. L. van der Roest.
8 Information in writer's possession, but as yet unpublished.
9 Ling, Roth, *Natives of Sarawak and British North Borneo*, 2, 210 (quoting Prof. Kiikenthal).
10 Hutton, I, 29, 392; Mills, I, 13, 109.
13 Haddon, II, 388.
14 Haddon, I, 200.
than to look at isolated customs without their context, and for this purpose I have chosen three widely separated areas. The first of these at which I wish to look is Fiji, where a very large number of points of culture are to be found associated, suggesting an intimate relation with Assam. Head-hunting customs may be taken first. Thomas Williams in his journal mentions the preservation of enemy skulls in Fijian 'temples' which offer a close parallel to the preservation of heads in a Naga morung. He also mentions a practice practically identical with that of 'touching meat' in the Naga hills, when he gives an account of the ceremonies gone through to confer honour upon Ratu Duadua 'on account of his having had something to do with knocking a man's brains out, or striking him with a club after someone else had killed him.' That is just what would be regarded as an adequate qualification for the assumption of a hornbill's feather by a Naga warrior, and I have elsewhere mentioned Colonel Wood's account of how his Naga clerk at Makwari was observed to spear a dead enemy (shot by a sepoy) with his umbrella, after which he assumed warrior's dress.

Williams also mentions the practice of human sacrifice at the time of building a house or temple, a practice which is still reported to take place across the Assam frontier and which has probably taken place inside it within my own experience of the Naga hills. The method there believed to be used, as in Polynesia, was to put the victim into the hole made for the post and step the post on top of him, the object of the ceremony being described as the provision of someone to hold up the post.

Brewster also mentions the necessity of a human sacrifice when building a club house in Fiji, and quotes one instance of a man being placed under the house-post of a warrior, who afterwards took the name of Nandu Rutama, meaning 'the man-post.' Brewster also mentions that measures require blood, a statement very reminiscent of a case in the Naga hills where vaccination against small-pox was supplemented by the taking of a head, and he likewise mentions the existence in Fiji of sacrosanct heralds who can go and come between warring villages quite safely in virtue of their office, as they can do in the Naga hills. It is also perhaps worth pointing out that the thatching of the ridge pole of a Fijian club house must be done by a warrior, as among the Sema Nagas; and there is conceivably some connection between the Fijian practice of putting fingers in split bamboo into the thatch as symbols of mourning and the Lhota practice of covering their ridge pole with bamboos split into five ends and always known as 'enemy hands.'

Another parallel between the Naga hills and Fiji is to be found in the practice of women turning out to welcome the returning warrior, a

16 Williams, Thomas, I, 552; II, 222.
17 Williams, Thomas, II, 374.
18 Hutton, I, 165.
19 Williams, I, 326, n.
20 Brewster, 75 sq.
21 Brewster, 75 sq.
22 Hutton, I, 160.
23 E.g., Hutton, X, 27.
24 Hutton, II, 45.
25 Mills, I, 34.
practice to which a parallel also existed among the head-hunting tribes of Kafiristan, where rice was showered on returning warriors, no doubt as a fertility rite comparable to the throwing of rice at a European wedding. The wearing of hair and teeth taken from an enemy’s head is reported by Waterhouse from Fiji and, in the case of hair, is still practised by the head-hunting tribes of Assam, who, at any rate in the case of the Konyak Nagas, seem at one time also to have worn enemy teeth, while they still like the Fijian warriors wear bleached pandanus leaves on their legs. In Fiji, as in the Naga hills, a plantain tree is a common euphemism for a human being for decapitation, etc., and the men over whom the Fijian war canoes were launched were actually tied to plantain trees to serve as rollers, which suggests a possible origin for the synonym. It was usual in the Naga hills for a village making peace, when its tale of heads was less than that of the other party to the negotiations, to demand so many ‘plantain trees’ to equalise matters, and to receive them in the form of slaves, who were decapitated to make the numbers equal on each side.

Many close parallels between Assam and Fiji are also to be found associated in one form or another with the cult of the dead. Brewster notes the existence in Fiji of a sort of ancestor worship combined with phallic forms and in some cases with an origin from a phallic rock or round water-worn stones. Identical cults exist in all parts of the Naga hills and are to be found as far south as the Arakan hill tracts. Phallic stone cists are made for the skulls of the dead in some Naga villages and over these cists ceremonies are performed to obtain the birth of children, just as in Fiji a barren woman oils and garlands a phallic stone for the same purpose. Both in Fiji and in the Naga hills ancestor spirits take the form of moths. In both areas there is a general belief in the path to be followed by the dead souls to the other world and in the perils that beset it, while the Fijian belief that the piercing of ears is necessary for recognition by relatives in the next world, or at least to avoid degradation therein, is reproduced by the Sema Nagas in Assam, just as the Ao reproduce the Fijian belief in the ultimate fate of the unmarried who succumb to the demon beside the road, as a defence against whom the Fijian buries a club with a dead warrior and the Naga a spear or a dao.

31 Waterhouse, II, 314.
32 Owen, Notes on the Naga Tribes in communication with Assam (Calcutta, 1844), p. 15.
33 Seemann, 31.
34 Brewster, 75, 234. Cf. Ellis, III, 1, 317. Where the expression ‘long plantain’ is used in exactly the same way.
35 Mills, II, 278, 279 n.
36 Brewster, 89; Waterhouse, I, 89.
37 Hutton, V; Mills, II, passim (v. index, s.v. ‘stones’).
39 Hutton, VIII.
41 Brewster, 287; Williams, I, 322; II, 247.
42 Hutton, II, 235.
43 Mills, II, 228.
44 Frazer, I, 464. Williams, II, 243 sq.
A very close parallel is also to be found in the Fijian practice of burying a whale's tooth with the dead man, who must throw it against a pandanus tree in this or in the next world. If he hit the pandanus tree with the tooth he obtains, according to Deane, 'a passport on his journey to the happy land.' According to Williams he knows that his widows have been strangled to accompany him. The Ao warrior is given no whale's tooth to throw, but is provided with a spear with which, having crossed the river of the dead, he must aim at a tree which he will find on the far side, calling out his own name as he does so. If he has lived an honest life he will hit the tree and obtain Paradise, if he has been a thief he will miss it and be side-tracked. It is worth noting that Waterhouse considers that the whale tooth is an innovation as it has 'probably not been in use much more than a century.' (He was writing in 1866.) He adds that costly clubs and 'staves' were similarly used as offerings like the whale's tooth, and in the Naga hills among the Ao, as among other tribes, the ordinary ceremonial gift is a decorated spear shaft without a head. It is probably significant that whereas the Fijian belief related to actual trees growing on specified islands, the Ao belief relates to a tree growing in the Land of the Dead and encountered immediately after crossing the stream which separates the land of the living from that of the dead.

One small point is perhaps worth mention. The demon on the road to the dead insists, according to the Angami Naga, on the dead man's eating either a bitter seed or a louse from his, the demon's, head before he passes him. Apparently in Thomas Williams' time it was customary in Fiji to eat lice from one's head, though this is not the case, at any rate in my experience among Naga tribes. Williams records that the dead in Fiji were dressed in new clothes. In the Naga hills to dream of a man dressed in new clothes is a certain presage of death, and I once had this brought home to me by one of my interpreters coming to me in camp in considerable consternation to say that my orderly, who had been left behind in Kohima was dead. He knew it because he had so dreamt of him that night, and the news of his entirely unexpected death reached us by runner two days later.

As in Fiji so in the Assam hills corpses must be fanned to keep the flies from settling, and as in Fiji so, if only occasionally, in Assam the coffin takes the shape of a canoe or appears to do so, although in the Assam hills a boat is rarely if ever used. In both places it is generally believed that life in the next world continues as in this. That if a man has been poor here he will be poor there and vice versa. In Bulotu,
the future world of the Fijians as of the Tongans, the air is so strong that mortals grow old very quickly,\textsuperscript{57} as in the Angami Whedzura,\textsuperscript{58} and the topsyturvydom of the Angami \textit{chuišênu}, when pesules put forth leaves and the grain will fly in the air and men run about to catch it, while their ears grow the wrong way on,\textsuperscript{59} has a precise equivalent in the Fijian Tavuki,\textsuperscript{60} as it has in the \textit{Apu Lagan} of the Karen of Burma, and possibly in the \textit{Apo Leggan} of the Kayan of Borneo.

Numbers of parallels appear in beliefs and practices current in the two areas. Both Fiji\textsuperscript{61} and the Naga hills\textsuperscript{62} believe in the separability of the soul from the body. It is conceived of as \textit{animula vagula blandula}, and when illness of the body is caused by the temporary absence of the soul the vagrant can be recalled by name. After death it may hang about its earthly haunts for three or four days,\textsuperscript{63} while belief in the plurality of souls in one body occurs in both areas.\textsuperscript{64} The symptoms of possession by a spirit causing a violent trembling of the limbs and rapid incoherent speech are the same in Assam and Fiji,\textsuperscript{65} as perhaps in many other parts of the world. So also the belief in the immanence of gods or spirits in stones is perhaps too widespread to be of value for the purposes of this comparison, though the use of baetylic stones is almost identical in both areas, and both areas firmly believe that these stones breed as if alive and produce children in the shape of smaller nodules.\textsuperscript{66}

Both in Fiji and among the Ao Nagas the fish appears associated with the marriage ceremony,\textsuperscript{67} while tattooing is applied to girls when they reach a marriageable age.\textsuperscript{68} In Fiji, as among the Konyak Nagas, we find girls taken from their subjects to attend a daughter of a chief going as a bride to a distant village,\textsuperscript{69} and in both areas the postponement of cohabitation after marriage is usual.\textsuperscript{70} In Fiji again, as among some of the Assam tribes, we find the practice of teknonymy,\textsuperscript{71} which Brewster compares to the Polynesian practice by which parents' sink into obscurity when their children arrive at the age of discretion.' One is reminded of the practice in Laruri in the Naga hills by which the parents abandon their house to their eldest son on his marriage and occupy a lean-to or separate hut of comparative insignificance.

In Fiji again\textsuperscript{72} a system is found known as \textit{vakandewa}, identical with that of the 'sentry' system by which letters in the Ao county can be sent direct from one end of the tribe to the other,\textsuperscript{73} though this system is not found in the majority of Naga tribes, at any rate in the south of the Naga hills. In both areas the official carver and meat distributor

\textsuperscript{57} Frazer, I, 462; II, 88. \textsuperscript{58} Hutton, I, 260. \textsuperscript{59} Hutton, I, 252; Mills, II, 108. \textsuperscript{60} Brewster, 237. \textsuperscript{61} Williams, I, 102, 127; II, 242; Deane, 156. \textsuperscript{62} Hutton, II, 200, 209. \textsuperscript{63} Waterhouse, II, 326; Hutton, II, 210. \textsuperscript{64} Williams, II, 224. \textsuperscript{65} Williams, II, 224. \textsuperscript{66} Seemann, 90; Hutton, II, 174, 253, 255. \textsuperscript{67} Williams, II, 170; Brewster, 51; Mills, II, 271. \textsuperscript{68} Deane, 23; Mills, II, 31. \textsuperscript{69} Williams, I, 329 n. \textsuperscript{70} Brewster, 196; Hutton, I, 222, 344; Shaw, 58 n.\textsuperscript{2} \textsuperscript{71} Brewster, 181; Parry, 238; Shaw, 140. \textsuperscript{72} Mills, II, 178.
is an important member of the village society.\(^{74}\) The Naga system of *penna* has already been mentioned and has very close parallels indeed in the Fijian regulations observed in such festivals as that of the *Ruku*.\(^{75}\)

One may also compare the sacramental offering of kava to the Fijian god with the little share of drink that every Angami or Sema Naga sets aside for the spirit of himself or of the place where he is. Similar beliefs are to be found in both areas in the existence of jungle pixies \(^{76}\) and in human beings who can render themselves invulnerable.\(^{77}\) Both areas possess the story of a tower of Babel,\(^{78}\) and the Angami system of land tenure is extraordinarily like that of Fiji.\(^{79}\) Points of this kind may be unimportant in themselves but their cumulative effect must be taken into account.

In material culture again there are a number of close parallels. The bachelors' dormitory (*mbure*) of course is very widespread, but it is remarkable that the game played with the beans of the great sword bean (*Entada scandens*), which is also widely distributed through the Assam Indonesian area, should have practically the same name (*walai : alau*) in Fiji and among the Sema Nagas.\(^{80}\) Both the Fijians and the Naga tribes use panjis,\(^{81}\) that is bamboo caltrops or spikes sharpened at both ends and very effective against a bare-footed enemy in warfare, and both indicate the road to be avoided by a following party by throwing down a handful of leaves in the path.\(^{82}\)

The Nagas, in contra-distinction to all their neighbours, are adepts in the art of wig making; so too the Fijians.\(^{83}\) But the most remarkable parallel is perhaps to be found in the use of a certain group of Angami villages of an unusual game which consists in throwing a reed dart on to a prepared surface of ground in such a manner that it soars again into the air and flies for a very considerable distance towards a mark at the far end of an open space.\(^{84}\) This game of the Dzunokeheno Angamis, called by them *cheda* or *phyelida*, is identical with the national game of Fiji known as *veitingsga*,\(^{85}\) a game which extends also to Samoa, where it is called *tanga ti'a*;\(^{86}\) while Ellis mentions it under the names of *aperea* in Tahiti and *pahe* in the Sandwich Islands.\(^{87}\) It is known in the plains of Assam under the name of the *s'ar* game; with what particular tribe there it is to be associated I am not certain, but probably the Kachari.

Psychological parallels must be used naturally only with the greatest caution, but to anyone acquainted with the Naga hills accounts of the

\(^{74}\) Brewster, 282 ; Hutton, II, 218 sq.

\(^{75}\) Brewster, 91, 93 ; Hutton, I, 192, 200 sq. ; II, 220 ; Mills, I, 26 ; II, 252.

\(^{76}\) Brewster, 88 ; Hutton, II, 192 sq.

\(^{77}\) Brewster, 99 ; Hutton, I, 243.

\(^{78}\) Williams, II, 253 ; Hutton, I, 265.

\(^{79}\) Williams, I, 106.

\(^{80}\) Seemann, 282 ; Deane, 16 ; Hutton, II, 106 ; Mills, II, 156.

\(^{81}\) Waterhouse, II, 316 ; Hutton, I, 44 ; II, 24, 171 ; Mills, II, 53.

\(^{82}\) Deane, 194 ; Hutton, I, 293 ; II, 265.

\(^{83}\) Williams, II, 78 ; Hutton, I, 22 ; II, 10, 16 ; Mills, I, 8, 13 ; II, 44.

\(^{84}\) *Man*, 1929, 112.

\(^{85}\) Brewster, 92 ; Deane, 16 ; Williams, I, 150 ; II, 162.


\(^{87}\) Ellis, III, 1, 227 and 4.
Fijians suggest so much that is similar in their general attitude towards life that it would be an error to omit all allusion to it. Thus, exactly like Nagas, 'the inhabitants of Namasi on being asked for their name will never give it when any one else is present to answer the question.' In both cases the explanation is perhaps to be found in an acute feeling of personal dignity considerably stronger than that which makes it polite among ourselves to apologise when asking a stranger for his name. I take, for further instances, a sample or two from Brewster, Williams and Waterhouse. The first two at any rate must have spent, I suppose, as long in Fiji as I did in the Naga hills, while the third was at any rate 14 years in Fiji.

Speaking of warfare they write as follows:—

'During the night one of them dreamed that their enemies were near and many in number; whereupon, with the greatest gallantry, they betook themselves to their canoes and hastened back to Samo-Samo.' A similar account, except for the canoes, might be given of 50 per cent. of raids and expeditions between independent Naga villages. Again, 'when parties on the war-trail met there was much interchange of abuse, boasting and challenging to mortal combat. Then should a man fall, the side to which he belonged promptly bolted. . . . I have managed . . . to piece together . . . records of nearly 300 years. Although they relate to a period of almost unbroken warfare, but little blood was actually shed. Communities of the trade villages become prosperous and arrogant, and excite the jealousy of their neighbours, who then enter into alliances with other clans and attack the common object of their envy. After desultory fighting, sacking and burning of villages the weaker side would flee further back into the almost inaccessible part of the hills. Both sides by that time would be tired . . . with the fighting, and the defeated party would get time to recuperate and reorganise. Then they would probably retaliate on their foes and turn the tables. It should not be inferred from this that the Fijians are cowards. We and they have different modes of thought—that is all. They will do many things that we should hesitate about.' The whole of this paragraph might have been written, without a word being changed, of the trans-frontier area of the Naga hills down to the present.

Again, 'a most striking feature in the arrangements for attack is the primary preparation for defeat. Many days are sometimes spent in preparing . . . paths by which to run way easily in case of defeat, while the subsequent attack may not last for many hours. . . . Frequently the army feigns retreat and draws out a sally from the town, a portion of which is almost invariably cut off by ambush. Generally the assailants will lie in ambush so as to cut off any small party which may happen to venture into their trap. Women and children are not spared. The slaughter of a pig is apparently equivalent to that of a man. "Seven were killed, the seventh being a pig," is sometimes reported.' Even so I have heard it reported in the Naga hills that seven heads were taken,

88 Seemann, 190; Hutton, I, 219; II, 143, 237; Mills, II, 270; Parry, 239; Shakespeare, 19.
89 Williams, I, 205.
90 Brewster, 59.
91 Waterhouse, II, 318.
two of which were *Mithun*, that is the gayal, *Bos frontalis*, the domesticated 'bison' of the Naga hills.

To quote Brewster again, 'It is really almost dangerous to save life, or do any great service to a native. It seems to give those so benefited an unanswerable claim on the person conferring the service.' He then proceeds to give instances of this; a point of view from which many officers in the Naga hills have suffered and no doubt continue to suffer. He gives another instance of Fijian mentality which might well be found in a Naga tribe. 'I remember hearing of a tribe... being much exasperated by the sneers of their heathen neighbours, who sent over to enquire if they had a plentiful supply of small mirrors or trade looking glasses. Being asked the reason of their question the reply was, "Oh, we thought you would like to practise before a glass how to put on a sanctimonious look like the Wesleyan native minister."' I am reminded at once of the long faces of the Ao elders of Changki, unmoved by Mr. Mills's joke, at which they laughed heartily afterwards in private, but not in public as unbecoming to Christian sobriety.

Waterhouse again refers to the rivalry between different clans in a single village, and to cases of the most cruel treachery of one to another with the help of strangers. One is reminded at once of numberless instances in the Naga hills of which it will be enough to cite the well-known incident reported by Carnegy in 1876, when a Kohima clan with friends in Muzuma suggested that the latter should send a war party on a particular day when they knew that the men of the Puchatsuma clan, occupying the next quarter to their own in Kohima village, would all be at the fields. The Muzuma party of 40 walked into the Puchatsuma quarter and killed everyone they could find there—one man, five women and twenty children. The adjacent clans of Kohima, who did not like Puchatsuma, stood looking on, and one of them remarked to Carnegy that it was fine sport, just like killing fowls. It may be added that both in Fiji and in the Naga hills stinginess seems to be abominated above all other faults, while both areas seem to have in common a certain sardonic use of metaphor which shows itself in such expressions as 'a trussed frog' or 'a long turtle' for a human being as a comestible (Fiji), 'floor rushes' for wives to be killed and laid in a chief's grave (Fiji), 'thatching' for spearing a sleeping foe through his roof (Naga hills), 'cultivation' for a surprise raid for the heads of neighbours working in their fields (Naga hills), or 'banana tree' for a human victim (both areas).

In most of the above instances the comparison has been between Fijian customs or beliefs and customs or beliefs in the Naga hills, which can be put down as specifically Naga. But there are a number of other parallels which are either shared by Nagas with other groups of which they are quite as typical or which are found in Assam without being found

92 Brewster, 60.
93 Brewster, 66.
94 Waterhouse, I, 53 sqq.; II, 5 sqq.
95 Brewster, 51.
96 Fison, 100; Mills, II, 278, 279 n.1; Hutton, II, 170.
in the Naga hills. Thus the Fijian reluctance to kill a chief,97 although it has its parallel in the taboo among the Konyak Nagas in shedding chiefly blood (where a chief has been murdered it has generally been by some method which avoids bloodshed), is also reported of the Lakher and the Lushei,98 where it is unlucky for even an enemy chief to be killed accidentally when fighting against one, and he is never killed wittingly.

Teknonymy 99 is more typical of the Kuki than the Naga, though indeed the Kachha Nagas and some non-Naga tribes practise it; the payment of 'bone prices' 100 is rather Kuki than Naga, in spite of occasional occurrences in certain tribes, and cross cousin marriage, which the Kuki advocates, is banned in the first generation by most Nagas. The use of caves for burial101 is also more Kuki than Naga, while the Fijian belief that spirits perambulate up and down the street, making it necessary that doorways should face across it,102 reappears in the same form among the Thado Kuki, who will not build a house facing down the village street, because if they did all the wandering spirits would drift in. The nose-flute 103 does not appear in the Naga hills at all, but is to be found on the north bank of the Bramaputra in Assam, and the practice of sitting as a sign of respect, though probably general in Assam, as in Fiji,104 is only specifically prescribed by the Assamese themselves, though on account of its association with the sanctity of the head it may probably be inferred elsewhere in Assam. The double canoe, which is associated in Fiji 105 with rank and quality, has possibly the same association in the Manipur state, where the rooks on the black side of a Manipur chess set take the form of double canoes as being superior to the single canoe which serves as a rook for its white opponent. One close parallel in Kuki and Fijian belief appears in the tradition of the serpent god coiled round the earth, whose movements cause the earth to quake.106 This god appears entirely unknown to the purely Naga tribes. Like the Thado Kuki or Lakher, also the Fijian uses a recessed grave, at any rate for his chiefs.107

I turn now to the Marquesas. Information as to these islands is much less easily available than information as to Fiji, but such accounts as we have very definitely suggest a number of comparisons with the Naga hills in Assam. In the Marquesas the practice of head-hunting, with the preservation and decoration of heads and with particular attention to the preservation of the lower jaw,108 has points in common with Naga

97 Williams, II, 39. 98 Shakespear, 58; Parry, 63.
99 Brewster, 181; Shakespear, 19; Shaw, 140; Parry, 238; Playfair, 147; Mills, 270.
100 Shaw, 56 n.2; Parry, 288, 418; Shakespear, 147, 166, 199; Deane, 80.
101 Shaw, 53 n.4
102 Williams, II, 245; Shaw, 85 n.1
103 Williams, II, 163.
104 Williams, I, 130; II, 38; Waterhouse, II, 340.
105 Waterhouse, II, 347.
106 Brewster, 81, 255; Waterhouse, I, 42; Shaw, 72.
107 Handy, 139. Cf. Ellis, III, 1, 308: 'The victors [in Tahiti] took away the lower jawbones of the most distinguished among the slain.'
head-hunting in general and Konyak Naga practice in particular. Again when a house was built a human victim was required as in the case of the Naga Morung, referred to before. Human victims were required for securing plentiful harvests or for breaking a drought, a practice entirely consonant with the general principles of head-hunting in the Naga hills. Similarly in the Marquesas human heads rendered fishing prosperous and the head was a particularly sacred part of the body and the shoulder only less so. Again we find heads brought home when the whole body could not be retrieved, and the name of the victim taken by the victor, a practice to which there is a near parallel in the Chang Naga one of a victor's naming his sons after the villagers whom he has conquered (and decapitated); and the common practice there of taking magical steps to attract the relatives of the killed to come and be killed themselves likewise in due course.

As in the Naga hills we find ancestor worship and the practice of making a small offering of the first mouthful of a repast, etc. We find memorial platforms extraordinarily similar to those built by Nagas, statues of the dead in wood and stone, cliff burial and the desiccation of the corpses of the dead, their disposal in canoe-shaped coffins and in mats accompanied by their best clothes and ornaments. We find the lips, the nostrils and the eyes of dying persons held together by their relatives, not to put an end to life, but to prevent the soul from escaping, and I have seen precisely the same offices performed by a Lhota Naga for his dying friend, while the funeral is accompanied, like that of many Assam hillmen, by a firing off of guns, which in Assam is variously explained as intended to frighten away evil spirits from the path of the dead or to warn the dead man's friends in paradise of his imminent arrival.

Like the Angami the Marquesan appears to believe in seven existences after that on this earth. He also believes, as many Nagas do, in alternative abodes of the dead in the heavens and below the earth. The Marquesan practice of communal taboo has already been mentioned, and even the verbal parallel between penant or pana-le and the penna and pini of Naga tribes may be extended by comparing émo, used with

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109 Hutton, IX. 110 Handy, 240. 111 Ibid.
112 Hutton, VI. 113 Delmas, 73.
114 Delmas, 63, 64. [Cf. La Loubère, Royaume de Siam, I, 405; F. Mendez Pinto, Voyages, etc., ch. 45.]
115 Delmas, 162, 172. 116 Delmas, 153.
117 Thus the Chang Naga Chief of Yongiendi called his eldest son Longkhong-Yanchu after a raid in which he had taken many heads off the Ao village of Lungkhung, and his second son Ongli-Ngaku after he had similarly raided Ungr shortly before his birth.
118 Delmas, 163; Hutton, II, 176; Mills, II, 204.
119 Delmas, 86 sq.; Hutton, I, 47 sq., 206.
120 Delmas, 118. 121 Handy, 112, 114.
122 Delmas, 114; Hutton, I, 227; Mills, II, 241; Parry, 401 [so also the Chakma of the Chittagong Hill Tracts between Assam and the Bay of Bengal; Lewin, Wild Races of S.E. India, 186; the Siyun of the Chin Hills in Burma, Carey & Tuck, Chin Hills Gazetteer, 193; and the Maori, Old New Zealand, 224].
124 Delmas, 52; Hutton, I, 184.
125 Delmas, 52; Voyage of the 'Duff' (1812), 354; Hutton, I, 184 sq., 414 sqq.
the same meaning in some islands of the Tabui group, with the *emung* (Lhota) and *amung* (Ao) of other Naga tribes. As in the Naga hills the soul is liable by wandering to cause sickness of the body, but can be recalled and brought back to it; and the Marquesan medicine man removes disease in a concrete form precisely like the Naga *thumomoi*, chafing the limbs with aromatic leaves and producing after a little massage the particular piece of 'dirt,' generally a fragment of rough stone, by sleight of hand or from under the tongue and pretending it came from inside the patient's body.

Seven appears in the Marquesas to be an unlucky number, as it is to the Angami tribe, and thieves are divined both there and in the Naga hills by looking into the globules of rain water that collect at the top of the stalk in the leaf of the wild arum, while seers of both areas practise ventriloquy.

Turning to their material culture, it is remarkable to find the taro cultivated in the Marquesas on terraced and irrigated platforms as rice is by the Angami, who, like the Marquesans, used to use the much valued conch shell as an article of barter almost as a currency, and who, like the Marquesans again, practise stilt-walking on the paved areas to be seen in most villages which form the scene of public entertainment. In the Marquesas again we find the Fijian game of vei-tingga, which the Angamis call *phyelida*, practised under the name of *teka*.

All these parallels in the Marquesas have so far been with the Naga rather than with the Kuki group, but two parallels appear with those in existence in the Marquesas of men who adopted the life and habit of women, a practice typical of the Lushei and found in some other Kuki-Chin tribes, and in the practice of sacrificing a victim for a dead man which formed an essential element of Marquesan funeral ceremonies, and which one may suppose was intended to provide for his service in the next world, as it was by the Kuki, Lushei and Chin tribes, who sacrificed victims on the graves of the dead, though they did not, like the Marquesans, devour their bodies.

Attention should probably be called to the apparent ferocity of the Marquesan character, differentiating them from the Polynesians of the South Pacific. It has been suggested that this ferocity was due to their rugged environment with its deep valleys and high ranges, but it seems more likely that it indicates the existence of some racial or cultural element absent in Hawai and Tahiti.

It is possible that Delmas's statement that among the Marquesans hospitality forms a road to social distinction indicates a system, or

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126 Delmas, 62.  
127 Mills, I, 26; II, 82, 252.  
128 Delmas, 76. Cf. note 62 above.  
129 Delmas, 76; Hutton, II, 231.  
130 Delmas, 133; Hutton, I, 252.  
131 Delmas, 134, 77; Hutton, X, 36 sq.  
132 Handy, 185; Hutton, I, 72.  
133 *Voyage of the 'Duff,'* 268; Hutton, I, 71.  
134 Frazer, 339 sq.; Mills, II, 155; Hutton, V.  
135 Handy, 297 sq.  
136 Handy, 103; Shakespear, 55.  
137 Delmas, 116, 118.  
138 Shaw, 78 n. 3; Parry, 206; Mills, II, 200.  
139 Delmas, 87.
the survival of a system, of a series of 'Feasts of Merit,' such as those by which social status is acquired in the Naga hills, but I have found no precise information on this point. As by the Dafla in Assam and as in Fiji, the nose-flute is used in the Marquesas, while the attitude of Marquesans to European immunity from the malign influence of wizards was stated to Delmas in almost the identical words used by a Naga to myself: 'You escape, because you do not believe,' a point of view which suggests that the Naga or Marquesan medicine-man fully appreciates the power of suggestion in magic, though his lack of an abstract vocabulary makes it difficult for him to put it into words.

I turn now to Madagascar. Although at the opposite extreme of the Oceanic area to the Marquesas, many similarities are found again with Naga cultures in Assam, particularly with those of the Angami tribe. As there, villages are built for security on the tops of hills with stone walls, ditches and stone gateways and surrounded with thick hedges of thorny acacia or of prickly pear, the stone gateways being defended with heavy wooden doors. In Madagascar, as among the Angamis and the Manipuris, the pantomimic war dance is popular, and the head is tabooed, as also the shoulder in the Marquesas and by some Nagas. In Madagascar again the plantain tree seems to be used as a human synonym and the blood of royalty must not be shed.

As in Assam we find various treatments of the dead, including their exposure on platforms and in canoes as well as in tombs and family vaults. Stoic tombs are placed by roads or in the centre of the village. They are lined with stone slabs and sometimes stepped in pyramidal form. Their place may also be taken by cenotaphs in the form of menhirs, and ancestor worship is much the same as it is among the Angami, and a similar importance is attached to funeral ceremonies, which are accompanied by musketry and the killing of large numbers of cattle in the court-yard in front of the house, the skulls of which are set up on the graves. Like the Ao, the Betsileo wrestle with their cattle before sacrifice. Graves themselves, as among the Angami, may only be moved during the cold weather, that is, I take it, between the harvest and the sowing. In some cases miniature houses are put up on the graves to accommodate the soul, and there is a concomitant belief in the Hill of the Dead to which every soul must journey. The dead again are dressed in new clothes and corpses

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140 Handy, 311.  
141 Delmas, 79.  
142 Sibree, 25, 28, 116; Ellis, II, 147, 359.  
143 Ellis, II, 328; Hodson, 67.  
144 Sibree, 241.  
145 Sibree, 3, 287, 152 sq., 180; Osborn, 343, 344; Sibree, 290, 300, 310.  
146 Ellis, II, 24.  
147 Ellis, II, 404, 410; Osborn, 234, 262, 280.  
148 Ellis, II, 63, 93.  
149 Ellis, II, 87, 206, 217 n.; Sibree, 288.  
150 Ellis, II, 389; Osborn, 229, 230.  
151 Wake, 26; Mills, II, 259, 379.  
152 Sibree, 119; Osborn, 232.  
153 Sibree, 287.
are carefully fanned to keep away the flies, and, in the case of the Vazimba, are given a double burial like the Khasi of Assam, where the belief in the snake monster known as the thlen is analogous to beliefs of the Vazimba. Like the Lushei, the Betsileo and Sakhalava draw off the putrefying liquors from the corpse.

Stones are dragged from a distance with a rope and, besides menhirs, spoken of as 'male stones' and put up as cenotaphs, a wooden post is erected as a circumcision memorial, clearly having some fertility association. Stone platforms are made and there is a cult of sacred stones on which, for instance, the Madagascar prince must stand, like the Rajah of Manipur. Monumental stones are erected in front of houses. A taboo is found on a chief's bedstead. As among the Konyak Nagas, royalty must contract marriages within the clan which would, except for royalty, be incestuous, though in Madagascar the clan is matrilineal instead of patrilineal as in the Naga hills. We find again a precisely similar belief in Madagascar to that in Assam, that the camera abstracts the soul. I remember myself making the pretty daughter of the Chief of Philimi most unhappy by taking her photograph, and she refused to be comforted until she got a print which she took to be the original. The possession of this secured her, in her opinion, from her soul's being taken to the hot plains, which would cause her sickness and death. Precisely as in the Naga hills among all tribes the Madagascar medicine-man cures illness by simulated extraction of 'dirt,' which the patient believes to have really come out of his body, though it is in fact palmed or 'mouthed' by the operator. The opprobrious names so often fancied in Madagascar are sometimes identical in meaning with those popular among Sema Nagas. The punishment of offences against society by the plundering of the offender's house is as popular in Madagascar as formerly in the Sema and Angami Naga country, and oaths are taken in exactly the same way as by many Nagas, by drinking water in which a bullet or some other metal weapon has been infused. In Madagascar also the Milky Way appears as the sign of the division of the seasons.

Turning to material culture, we find the Hova using spears shod with a point at the butt-end for sticking into the ground like all those in the Naga hills. Putting the weight is found as an indigenous sport,

as also the practice of boxing with the feet.\footnote{177} Peg-tops\footnote{178} are used by children, who also amuse themselves in making clay figurines of cattle very much like those of the Angami.\footnote{179} The hearth-stone is made precisely as in the Naga hills, with a trivet of three stones erected in a clay base and screened above by a two-decker bamboo shelf.\footnote{180} The method of pounding paddy\footnote{181} and the patterns of piston bellows\footnote{182} and 'rat protectors'\footnote{183} under granaries are typically Indonesian, extending likewise to Assam, and the use of 'house-horns' (Hova tandro-trano, Angami ki-ka, with precisely the same meaning, though the Sema word means 'snail horns') ornamented with wooden birds is typically Angami (Dzunokeheno). While the Y-shaped posts erected (e.g.) as a circumcision memorial in Madagascar,\footnote{184} and associated therefore with fertility rites, are familiar among all Naga tribes,\footnote{185} the Betsileo apparently crown their stone monoliths with iron horns.\footnote{186} Typically Angami also are the stone-revetted irrigated terraces for growing rice,\footnote{187} while in Madagascar channels are used to carry liquid manure from the village midden to the terraces\footnote{188} exactly as they are in some villages of the Dzunokeheno group of the Angami tribe, a group which we have already seen has a particular connection in one or two respects with Fiji and the Marquesas. The use of euphorbia and aloes for hedges\footnote{189} is closely paralleled in the Naga hills and Manipur, and the use in Madagascar of the scarlet lamba\footnote{190} as the insignia of royalty is very suggestive of the same area, even the word lamba being Manipuri as well as Hova. Bark cloth,\footnote{191} it is true, is only paralleled in the Garo hills in Assam, but, like the use of spiders\footnote{192} as food, is perhaps not an entirely fortuitous coincidence. In both areas ownership is indicated by a bunch of grass on a reed, and as in Fiji again a path is barred by throwing down a bunch of leaves.\footnote{193} The use of a stone as a weapon, not thrown but held in the hand,\footnote{194} perhaps seems an obvious means of damaging an opponent, yet in twenty years I do not remember any case of its use in any Naga tribe except the Angami; the Angami have just the clan antagonism reported of Madagascar,\footnote{195} and when a wooden utensil or tree is being dragged to the village a young buck will jump on to it and shout and gesticulate to urge on the pullers, exactly as Ellis describes\footnote{196} in that island. But for

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\footnote{177} Sibree, 32; Osborn, 356; Hutton, II, 109. \\
\footnote{178} Sibree, 32; Hutton, I, 104; II, 105 sq.; Mills, I, 84; Shaw, 158. \\
\footnote{179} Sibree, 32; Hutton, I, 55. \\
\footnote{180} Ellis, II, 447; Sibree, 7; Hutton, I, 53; II, 39; X, 67 sq.; Parry, 69. \\
\footnote{181} Ellis, I, 203; Parry, 133; Smith, 39; Peal. \\
\footnote{182} Peal; Ellis, I, 308; Sibree, 331; Wake, 26; Hutton, I, 63; II, 52 \\
\footnote{183} Smith, 144, 159; Parry, 107. \\
\footnote{184} Sibree, 3, 298, 319. \\
\footnote{185} Wake, 27. \\
\footnote{186} Hutton, III. \\
\footnote{187} Ellis, II, 247, 445, 448; Sibree, 21; Hutton, I, 72. \\
\footnote{188} Osborn, 281. \\
\footnote{189} Osborn, 419; Ellis, II, 444; Sibree, 58, 65, 105. \\
\footnote{190} Osborn, 194. \\
\footnote{191} Sibree, 330; Walker, G. D., 1927, Man, 5. \\
\footnote{192} Sibree, 344; Hutton, I, 95. \\
\footnote{193} Sibree, 172; Hutton, II, 68; I, 293. \\
\footnote{194} Ellis, II, 270; Hutton, V, 72. \\
\footnote{195} Ellis, II, 274; Hutton, I, 109. \\
\footnote{196} Ellis, II, 478.
a parallel to the whimsical choice of such personal names as Radeboka, i.e. the 'day book' of a hospital, one needs to go to the Khasia hills in Assam, where names such as Ka Mediterranean Sea, U Water Kingdom or Shakewell Bones are, or were, familiar. Matrilineal descent appears in Madagascar as it does in Khasia hills, though in most parts of the Assam hills it is now submerged. The use of the ideochord is more elaborate in Madagascar than among the Kuki tribes, but is essentially the same instrument (I refer to the bamboo guitar in which the strings are formed by strips cut in the outer bark and prised up by wedges underneath at each end of the strip), and exactly on the same principle as many village gates in Assam, particularly among the Kuki-Chin tribes, are the doors described by Sibree in Madagascar as made of poles—bamboos in Assam—hung from a cross-piece which passes through a hole in each. Kuki again, but not Naga, is the story of the escape from the ogre by throwing down a feather which becomes a forest, etc., and apparently Kuki is the Malagasy (Betsileo) practice of burying with an air tube of bamboo let down to the head through the earth, as among the Sea Dayak and Kayan of Borneo, in order that the soul may have ingress to and egress from the buried body. I say apparently Kuki, because this practice is typical of the Thado at present, but it is also reported of the Kachari, and of the Santal, so that it may, like some other Kuki features, have been taken over from previous matrilineal (?) inhabitants. In the case of the Santal the tube seems to have survived a change from burial to cremation, as it now consists of a reed let through the lid of the pot which contains the cremated remains of the dead.

The parallels which I have given are, I think, adequate to show the cultural connection between the Assam hills and the three widely separated areas in Oceania with which I have dealt. It is pretty clear that in Fiji and in Madagascar, and probably also in the Marquesas, this identity of culture, in so far as it exists, is not that of a single culture, but rather of a complex of cultures in each case. It is clear that Assam may conceivably throw some light on the Indonesian problem, as the stratifications can, at any rate to some extent, still be traced. The last immigrants are undoubtedly people of Kuki and Kachin affinities. There is a clear tradition among the Chins of the Arakan hill tracts pointing to their migration down the Chindwin Valley, no doubt throwing off parties which must have penetrated the Assam hills from the east on the way, after which one portion of the Kukis at any rate seem to have worked up northwards again from the Bay of Bengal, a movement which has barely ceased, if it has ceased, in the present generation. It would seem that the Kayans of Borneo probably formed part of the same movement. A tradition quoted by Hose and McDougall assigned the

197 Sibree, 348. 198 Ellis, II, 81, 201.
199 Osborn, 360; Shaw, 151; Parry, 185.
200 Sibree, 239 sqq.; Shaw, 105.
201 Sibree, 305; Shaw, 55 n.2; Hose, Natural Man, 213.
202 Endle, The Kacharis, p. 47.
203 Census of India, 1931, 1, 111B, 102 (Bodding).
204 Fryer; Shaw, 17 n.
205 Pagan Tribes of Borneo, 1, 15.
arrival of the Kayans in Borneo to the earliest years of the fourteenth century A.D., a date which fits well enough with Kuki and Tippera tradition.

Apart from such preceding migrations, of which there may have been many originating in movements in the Chindwin Valley caused by this southward Kuki Kachin migration, and of which we probably have a memory in the traditions of the Angami Lhota and Ao movements from Manipur westwards, the two previous cultures in the Assam hills seem to have been definitely matrilineal and to have belonged to two types. One of these—and presumably the later—seems to have been analogous to the present Khari and Synteng cultures, the other to that of the Garo and of the Kachari of the Assam plains. The Khari migration clearly came from the east, and the parallel culture in Tonkin to their earliest remains in Assam is dated by Coedes to about the beginning of our era. The Garo-Kachari peoples seem to have migrated from the north bank of the Brahmaputra, and while the Kachari is now predominantly patri- lineal, as the Garo is matrilineal, both may still be said to be in the process of change as the result of contact between two systems.

It is interesting to notice that in Madagascar the Vazimba, who preceded the Hova as immigrants, had a number of features in common with the megalith-using Khasi, not all of which were subsequently adopted by the Hova. The latter, for instance, built in wood, whereas the Vazimba used stone. One may also observe that Hocart, writing on the early Fijians, is inclined to think that the more civilised community was swamped by barbarians before the more recent migration of Polynesians from the east. Undoubtedly the Naga tribes at present represented by the Konyak Nagas in the north and to a lesser degree by Kachha Nagas to the south of the Naga hills, are associated with a more civilised culture in some respects than that of the intervening tribes who have come up from Manipur, always excepting the Angamis, who are in many respects sui generis and who probably have incorporated a very great deal of the civilisation which preceded them on their present sites. Indeed they speak of the time when their women wore four-inch petticoats like those of the Konyak tribes, and when they used to expose their dead on platforms—except in the villages of the Dzunokeheno group. It is just that group in which the Fijian Veitingga game is so popular, and in which the house-horns carry birds like those on Malagasy houses. Veitingga, as already mentioned, is also known in the Assam Valley by the name of s'ar khela and used to be played on roads or in village streets, though now almost entirely obsolete. It is still the Dzunokeheno (i.e. water-born villages) in which the conch shell ornament so suggestive of the sea is most popular. They do not, however, claim the sea, but a local stream, as the water of their ancestry, and they are the only Naga tribe that I know of, except the isolated village of Laruri on the Burma frontier, which repudiates any tradition of migration from elsewhere. The Angami are now, like the Kachha Naga, completely democratic in their institutions, but the Konyak tribes in the north still retain taboed

206 Hutton, I, 6 sqq. 207 J.R.A.I., 49.
and sacrosanct chiefs; chiefs who have to be carried sometimes lest they touch the ground and destroy the fertility of the soil; chiefs who must contract marriage with their own clan, which would be incestuous for anyone else, if they are to have a legal heir; chiefs whose blood must not be shed on any account, who have been known to be driven out, strangled or otherwise got rid of by the villagers, who are probably derived ultimately from a different stock.

One important feature of the Konyak tribes, shared, it is true, by their neighbours the Aos, and in a ruder fashion by the Sangtam, Chang and Yimtsungr of the east, is the possession of enormous slit wood gongs to which I give the name 'canoe gong' on account of their shape. S. E. Peal was the first to report on these gongs, which he called 'canoe drums'; Professor Henry Balfour calls them xylophones, and the only reason that I do not adopt his term is that I prefer to keep that name for the more usual type of xylophone consisting of a number of slats of wood giving different notes when beaten which is found among the Kuki, though not among the Naga tribes. These canoe gongs are the basis of an important cult intimately associated with head-hunting, and strongly suggestive of much that is associated with canoes in Oceania.

The true canoe gong with carved figure-heads and long hull like that of a dug-out is almost entirely limited to the Konyak, Ao, Chang and Sangtam tribes, and of these four undoubtedly the Chang and the Ao contain a large admixture of Konyak blood. The Sangtam only use a typical canoe gong in those villages which march with the Ao and Chang country. Further south the shape is much less elaborate, and the Yimtsungr to the east of them used a mere hollow tree-trunk. South of the Sangtam tribe the canoe gong completely disappears except for the following instance: the Tangkul tribe use a remarkable form of gong hitherto, I believe, unpublished, which might be described as resembling an inverted boat, the two ends of which are skeleton, while the centre part consists of the usual slit gong of more or less cylindrical type. The Angami use an unornamented wooden vessel of similar shape (without the skeleton ends) for the reception of liquor in bulk on ceremonial occasions, and one recalls Ellis's account of the man of Rurutu who came off to meet him 'at a distance of two miles' from the island in a wooden food-vessel 6 feet long and 18 inches to 2 feet wide. A smaller slit gong of somewhat similar pattern, but much simpler, is used for scaring the birds from their fields by the Kachha Naga. Further south again the Zanniat Chins, who, unlike the other Chins, have a democratic organisation, have a small slit gong not more than 6 feet long very like the Angami vat, while the Ngawn Chins use one of the same size not unlike the South American teponatzli, and put food in it on the occasion of a ceremonial dance. A 'wooden drum' also appears in Arakan as one of the prized possessions of the pre-Burmese king; it may or may not have been a 'canoe gong.'

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208 Peal, op. cit.
209 Mills, II, 76 sqq.; Smith, 47; Hutton, X.
210 Hutton, I, 57.
211 Ellis, III, 3, 400.
212 Personal information from Mr. N. Stevenson of the Burma Frontier Service.
213 Scott and Hardimann, Gazetteer of Upper Burma and the Shan States, I, ii, 402.
It is interesting to observe that in South America the canoe gong appears to have developed independently from a hollow tree. Nordenskiöld bases this conclusion partly on the fact that these signalling gongs are beaten with a rubber-covered mallet to which, he says, nothing similar is known outside America. He comes to the conclusion that the invention of slit gongs arose from a practice of sending out signals by beating on hollow trees in the forest; that this led to carrying such hollow trees home to villages, and then to beating instead on canoes or wooden troughs. He quotes Faraba to the effect that the Amahuaca Indians of Peru occasionally signalled by striking with a heavy mallet upon the flat root of the Alatea tree after having stripped the bark from it but without cutting it off. He goes on to describe 'a large wooden gong . . . suspended by one end whilst the other rests on the floor of the pile beam house: 'It is beaten with two wooden mallets.' Again, 'the resemblance between a gong of this kind and a canoe is so great that it is quite reasonable to suppose that the Indians formerly used as gongs their canoes which are often drawn up underneath the floor of their pile houses, or laid on stagings.' It is, of course, possible that the canoe gong of the Naga hills has similarly developed from a tree trunk, but since we find no example of signalling by hammering on trees we are perhaps entitled to argue that the process in Assam has been the other way and that the smaller slit gongs, or the hollow tree trunks, used by some villages are degenerate forms of the original gong which started as a canoe, and it is possibly significant that in the Kachin story of the great flood the two survivors escape drowning in 'a large oval-shaped drum.' On the other hand, it must be admitted that a simple form of slit gong occurs in Yunnan, as it does in Malaya and in Borneo, suggesting either marginal degenerations from a developed type in Assam, or possibly simple types from which the Assam one might have been elaborated. The real argument, therefore, for the canoe gong's being a survival from a real canoe rests on its associations with head-hunting and a typical canoe culture.

Now the Naga canoe gong is closely associated with the men's house, and generally, if not kept in it, it is kept in an annexe. It is in some respects treated almost as an idol and tremendous effort is expended on

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214 A similar rubber mallet, however, is reported to be widely used in Africa, and it seems just possible that the idea may have been taken to S. America by negro slaves.

215 Nordenskiöld, 44, 45.

216 Nordenskiöld, 46.

217 Hanson, The Kachins, 112.

218 'In the beginning of the first moon they have a feast. A large tree is scooped out which is called a 'trough'; both men and women take a bamboo and strike it; the sound is like a drum. Then they play.' Chinese account of the Pei Chong-Kia, aborigines of Kweichau in Yunnan, quoted by Colquhoun in Across Chryse, II, p. 308.

219 Evans, Among Primitive Peoples in Borneo, 133; Ling Roth, Nations of Sarawak and British N. Borneo, II, cxcvii, 263. He quotes Schwaner to the effect that the Orang Ot, a very primitive hunting tribe, beat violently on a hollowed stem to assemble the whole tribe. He also gives the name for the slit gong in Dutch Borneo as tenkuang, which is almost identical with one of the Naga names—tingkhong.
carving it and dragging it up to the village. All human heads brought in are first placed on the canoe gong, at any rate by the Ao, suggesting the Marquesan practice of decorating the prows of their war canoes with the skulls of their enemies. When the gong is dragged up to the village over wooden rollers, such as those used in launching a vessel, the blood of the sacrificed animals is poured on to it, and in the old days any stranger, whether friend or foe, who came to the village on the day when a new drum was dragged in was killed in order that his head might adorn the drum and his soul inhabit it. Indeed, until a head had come in, or had been brought in for the drum, a fence was put round it which could not be removed, nor could the drum be beaten until the young men had been out and fetched a head to remedy the defect. This head was first laid on the new drum.

The parallel with Melanesian canoe practice is here very close. Codrington writes \(^{220}\) as follows: 'In the eastern Solomon Islands, if no victim was met with in the first voyage of a new canoe, the chief to whom the canoe belonged would privately arrange with some neighbouring chief to let him have one of his men, some friendless man probably, or a stranger, who would then be killed, perhaps as he went out to look at the new canoe. . . . Further west also captives were kept with a view to the taking of their heads when new canoes were launched.' He goes on to give an example in a footnote: — 'The chief of Ravu bought his peko [war canoe] . . . for a large sum of money. It was brought over secretly and put into a . . . canoe house, where it stood till a head should have been procured. . . . In the morning a single man came by . . . in his canoe . . . they caught and killed him, set up his head at the prow of the [newly bought] canoe and paddled back to Ravu with shouting and blowing conch shells.'

Nowadays in the Ao country a mock raid takes the place of a real one, but even this chastened sacrifice leads to a great success in hunting and in agriculture. The Ao gong nowadays wears a necklace of basket balls representing heads. Real heads were never used in this way, although they were laid on the gong when first brought in. These basket-work ornaments perhaps afford a parallel with the carved head which formed part of the figure-head of the Melanesian canoe. The figure-head of an Ao canoe is generally in the form of a buffalo or gayal head, that of the Konyak tribes an elephant, buffalo or hornbill head, but Peal,\(^{221}\) writing in 1893, remarks that the Konyak figure-head is (as depicted in his drawing) a crocodile, although 'there are no crocodiles in these hills,' and he points out that it is a familiar decoration in Indonesia and the Pacific. Although I have covered most of the ground visited by Peal in the last century, I have never seen any figure-head resembling the head of a crocodile, so that this tradition has apparently disappeared in the forty years since he visited the Naga hills.

It has occurred to me that the instruments used for beating the Naga canoe gong may conceivably be degenerate paddles. The ordinary type is more like the dumb-bell than anything, but often one end of the dumb-

\(^{220}\) The Melanesians, 297.

\(^{221}\) J.A.I., 22, 252.
bell takes an ornamented form such as the hornbill’s head,\textsuperscript{222} and in any case this ‘dumb-bell’ is not unlike a paddle in which the blade has degenerated to proportions similar to those of the handle.

F. E. Williams, writing\textsuperscript{223} of the Pairama ceremony in the Purari Delta in Papua, tells us that ‘when a successful hunt returned at evening the corpse of the victim was borne from the canoe to the ravi amid great enthusiasm. The men uttered that prolonged shout or roar which has a singularly exciting effect upon the listener, and rattle their paddles upon the sides of the canoes with the rhythm called raruki raruki. . . . On the following day the . . . hunter who first brings down the victim . . . is paraded in triumph through the village standing astride the canoe and balancing himself with a spear.’ It was formerly the custom of Meithei to signal across the Logtak Lake in the Manipur State in Assam by beating with their poles or paddles on the sides of their dug-outs as the Nagas do on a canoe gong, and I am further told by Mr. William Shaw, who served many years in the Manipur State, that some Kabui villages which have no canoe gongs still have the tradition of having used them once, while in Kabui Khulen village a sort of boat, with a high prow, is dragged in every year at the Harvest Festival ‘for all who have died in the past year.’ The best dressed of the young men rides on the boat, while there is a tug-of-war between the two clans of the village, one pulling at each end of the boat by ropes attached to pierced lugs left on when fashioning this dug-out, which is known as the thing-khutong—the plank to which a dead body is ordinarily fastened for burial in that village being called thingkhu. It must, I think, represent a boat or a boat-shaped coffin and be associated again with the fertility of the crops, so largely bound up both with the spirits of the ancestral dead, and of dead enemies, while the riding of the boat by the young warrior is reminiscent of the Pairama ceremony described by F. E. Williams.

Boat-shaped coffins are found occasionally in several of the Naga tribes, particularly in the Konyak country, where in one village at any rate they are associated with a tabooed chief, and it is worth noticing that a stone is put up by the Fijian ‘spirit house’ for each corpse brought in,\textsuperscript{224} precisely as the Konyak Nagas put up an erect stone outside the men’s house for each head; and it is also remarkable that in one case, at any rate, there seems to have been a close association between the Fijian war canoe and the gong known as lali, since the chief Rokona named his war canoe Vatutulali, after his large gong.\textsuperscript{225}

The Samoans have a similar gong known as longo, the sound of which—according to Brown—will carry for 20 miles under favourable conditions. Brown also mentions that the Samoans struck the sides of their canoes with the handles of their paddles to mark time.\textsuperscript{226}

One more parallel is worth indicating in connection with this subject.

\textsuperscript{222} Vide illustration, Mills, II, 77.
\textsuperscript{223} J.R.A.I., 53, 385, 386. He also describes with reference to the same ceremony the rhythmical pounding with bamboo of an old broken canoe laid along the ravi floor.
\textsuperscript{224} Seemann, 178; Hutton, X, 41.
\textsuperscript{225} Seemann, 197.
\textsuperscript{226} Melanesians and Polynesians, 350.
Writing in the *Journal of the Royal Society of Arts* for February 1937, La Valette illustrates the upilted roofs of a branch of the Toradja tribe in Celebes, which he says are deliberately got from the prow and stern of a canoe, and are 'bound up with the tribal traditions of their ancestors, who originally arrived from a country overseas to which the spirits of the dead must return.' The roofs he illustrated are almost identical with forms common in one branch of the Konyak Nagas, east of the frontier of Assam.228

I have elsewhere suggested a possible migration from Indonesia, and migrations from Indonesia to Ceylon and South India are placed by Hornell at about the beginning of the Christian era. I cannot help thinking that if, as I am tempted to believe, there was an Indonesian migration which swept upwards northwards into Assam before the Kukis came south, it must have been at an earlier date than that at any rate; there does seem to have been some expansion in many directions from Indonesia at a date which perhaps precedes the dates suggested by Coëdes and Colani and the megalithic civilisation of south-east Asia. It would be interesting to know how far the stratifications of cultures in Oceania will correspond to the apparent succession in Assam of an Oceanic canoe culture, a matrilineal megalithic culture and that of a more recent patrilineal one associated with the Kayan and Kuki. The principal point which I wish to make, however, is that the hill cultures of Assam correspond to other distant cultures or combinations of cultures, all of which appear to be marginal in distribution from an Indonesian centre, and that there is some ground for supposing that migrations of culture, if not of people, have taken place from some centre in or near the Indian archipelago in various directions, one of which terminated in Assam.

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228 Hutton, X, pl. ii, fig. 5, and pl. xiv, fig. 2.


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SECTION I.—PHYSIOLOGY.

HEAT PRODUCTION, NUTRITION, AND GROWTH IN MAN—SOME NEW VIEWS.

ADDRESS BY
E. P. Poulton, M.A., D.M.,
President of the Section.

Section I is the Section of Physiology of the British Association; but its deliberations have commonly traversed a wider ground than might have been anticipated from this title and the Section of "Medical Sciences"—the 'Institutes of Medicine' of the Scottish Universities—might be a truer description, though I do not wish you to infer that pure physiology has been neglected. In doing me the honour of asking me to preside for this year, I feel that you have taken this wider aspect into account, so that before dealing with the technical part of my Address, I may be allowed to give my view on one disquieting tendency that relates to the Voluntary Hospital system and the health of the community. The facilities for medical research in this country have increased out of all proportion since 1914, when the Medical Research Committee (forerunner of the Medical Research Council) was formed, and I should not like to miss this opportunity of paying my tribute to Lord Nuffield for his unique benefaction to my old University. But, if we except the whole-time research and teaching posts, there are still funds available to pay the research expenses of those who are willing to give their spare time to medical research in the course of their teaching and practice. As one who has benefited by this, as I think, wise provision, I am anxious that my successors should not be less favourably situated, and I would appeal to those with funds to distribute not to neglect this need in their desire to provide for whole-time research posts.

If the present outlook of medical research is relatively bright from the financial point of view, how about its application in medical practice? Here the story is different. If the result can be taken in the form of a pill its popularity is assured and valuable advances in treatment have been achieved; but if the discovery means that some trouble must be taken or an apparatus purchased, then, however valuable, in some parts of the country it will remain unused for years, and for this I am afraid the straitened circumstances of the voluntary hospitals must be held largely responsible. At present few voluntary hospitals will spend
money on novel apparatus if it can possibly be avoided, though when apparatus is provided, as experience shows, it will be freely used. It is interesting that this slow application of discovery has been noted in commercial spheres, and in a recent research benefaction to the Royal Society part of the money can be used for popularising the results of research. Such a provision is eminently desirable in medicine, and, in commending it to the pious benefactor, I would point out that much good could be done by a comparatively small sum of money, since in the first place it need only be applied to the voluntary teaching hospitals. When once the medical student—the future doctor—has become accustomed to a new method or a new apparatus, its spread throughout the country cannot be so long delayed.

**INDIRECT CALORIMETRY.**

In estimating the heat production of an individual the oxygen intake and the carbon dioxide output are measured. After allowing for protein metabolism the oxygen intake is converted into calories of heat generated, by multiplying it with a factor which depends on the respiratory quotient (volume of CO₂ produced/volume of O₂ absorbed). These multiplying factors were calculated originally by Zuntz and Schumburg (1901) and are based upon (a) the heats of combustion of carbohydrate and fat, (b) the chemical composition of carbohydrate and fat, and (c) the theory that when the respiratory quotient has the value unity carbohydrate alone is oxidised in the body and when the respiratory quotient has a value equal to 0.707 fat only is being oxidised, and at intermediate values of the respiratory quotient corresponding proportions of carbohydrate and fat are being oxidised. This method of calculating the heat produced by an individual is known as indirect calorimetry. The basal metabolism or basal metabolic rate of American authors or 'standard' metabolism of Krogh and Lindhard is at present defined as heat production in the morning before breakfast, fourteen to sixteen hours after the last meal of the previous day (the post absorptive condition) with the subject lying at rest.

The theory that the respiratory quotient, the term introduced by Pflüger, indicates the proportion of carbohydrate and fat that is being burnt in the body has been evolved in physiology since Regnault and Reiset's observations (1849) and Reiset's observations (1863) on various animals. These authors found that the proportion of carbon dioxide given out to the oxygen taken in depended on the food taken rather than on the type of animal investigated. In rabbit D, for example, this ratio—in other words, the respiratory quotient was 0.95 when eating carrots, 0.907 with bread and oats and 0.707 when hungry. In the case of a dog F, with bread the respiratory quotient was 0.943, when hungry 0.724, and with mutton fat 0.694. In 1898, M. S. Pembrey, in Schafer's *Textbook of Physiology*, wrote that 'an animal fed on a vegetable diet has a quotient

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1 Few references are given in this Address as they appear in Guy's Hospital Reports, 1934-37: *84*, 473; *85*, 56, 447; *87*, 151.
closely approaching unity, for its chief food, the carbohydrates, contains enough oxygen to combine with the hydrogen to form water; that a carnivorous animal has a quotient about 0.74 and an omnivorous animal such as man a somewhat higher quotient; and finally, that even a herbivorous animal has a low quotient during starvation, for it then lives upon its own tissues.' The complete evolution of the theory may be said to date from Zuntz and Schumburg's calculations, for since that time the respiratory quotient has been generally regarded as providing a quantitative measure of the combustion ratio in all circumstances—after food, in the post-absorptive state and during starvation. For convenience this may be called the theory of the 'variable combustion ratio,' since this varies with the respiratory quotient.

**DIRECT CALORIMETRY.**

Direct determinations of the output of heat in calorimeters have been made over many years; but up to the end of last century, when the Atwater-Rosa respiration calorimeter was constructed, the complete respiratory exchange was not measured simultaneously with the direct calorimetric measurements. The heat output of man and animals, under basal conditions, has been measured directly in a calorimeter by Benedict and Carpenter, DuBois and his colleagues and Murlin and Lusk, and compared with the heat output calculated indirectly by means of the Zuntz-Schumburg figures from the oxygen intake and the carbon dioxide output, which were measured simultaneously. The results obtained have been held by their authors to justify the conclusion from average values that the agreement between the two methods was sufficiently satisfactory to give support to the theory of the 'variable combustion ratio' outlined above.

However, this theory has not escaped criticism. Benedict and Carpenter, when describing their observations on the metabolism of subjects after a meal of carbohydrate, state (p. 173) that in many instances the agreement between direct and indirect calorimetry is extremely unsatisfactory because of 'the abnormal conditions previously outlined which obtain when excessive amounts of carbohydrate are ingested.' Respiratory quotients below 0.707—the theoretical quotient of the combustion of fat—have not infrequently been obtained; these are impossible on the theory, since they can only be explained by the conversion of fat into some more highly oxygenated substance such as carbohydrate. These low quotients have been attributed by staunch upholders of the theory to experimental error.

The partial conversion of fat to carbohydrate was supported by M. S. Pembrey, who became one of the earliest critics of the theory, after observing very low quotients in hibernating animals. Observations of this kind date back to Regnault and Reiset who, when investigating the metabolism of marmots, found, in the case of marmot C, for example, a respiratory quotient of 0.399, when the animal was asleep and a quotient of
0.686 when it was eating. Gorer in a complete review of the subject concludes that there is adequate proof of some such conversion.

No doubt exists as to the conversion of carbohydrate into fat in the animal body, and respiratory quotients above unity have been freely allowed. But even here difficulties have arisen, because it is difficult to imagine that such a conversion begins de novo and just at the point when the value of the respiratory quotient exceeds unity and that the metabolism of fat ceases completely at exactly the same point. Cathcart and Markowitz have pointed out this difficulty, but their observations on the rise of the respiratory exchange and respiratory quotient after giving sugar, which had been previously studied by Higgins, do not prove that such conversion takes place below a respiratory quotient of unity. They qualify their criticism of the theory in the following words: 'We do not wish to cast doubt on the validity of the calculations of indirect calorimetry when the experiments extend over several hours; indeed, we are whole-hearted believers in the method under these conditions. We even believe that when conditions in the body are stabilised (as they presumably are in the post-absorptive condition when basal metabolic rates are commonly determined) agreement between indirect and direct calorimetry will be close. But where metabolism is actively proceeding in the organism, as may occur in short experiments following food, this close agreement cannot be expected.' Krogh and Lindhard go further than Cathcart and Markowitz when they suggest that the conversion of carbohydrate to fat on the one hand and fat to carbohydrate on the other begins towards the middle range of respiratory quotients (i.e. 0.90 upwards and 0.80 downwards), but it is difficult to see how any argument can be based on observations in which the heat itself was not determined.

Dale and his co-workers, and Cori and Cori, suggest that the administration of insulin to depancreatized and normal animals brings about oxidation of carbohydrate and so raises the value of the respiratory quotient, but in depancreatized animals the respiratory quotient may be fairly high—up to about 0.80, so that the power to utilise carbohydrate is not lost. In the more severe forms of muscular work respiratory quotients greater than unity have been observed, which can only mean some reduction of the carbohydrate—a conversion of carbohydrate to fat; but this is unlikely if carbohydrate is the main source of energy in muscular work, a hypothesis that has been put forward to explain quotients up to unity which are obtained when muscular work of moderate intensity is performed (Furusawa).

A Fundamental Error in Indirect Calorimetry.

The most complete study of direct and indirect calorimetry in normal man under basal conditions is that made by Benedict and Carpenter. In the experimental work carried out by these observers, the greatest precautions were taken to eliminate, or to compensate for, all known sources of error. The accuracy of the respiratory calorimeters used was checked
by control experiments in which alcohol was burnt in the calorimeter under experimental conditions and the measured heat, oxygen consumption, and carbon dioxide production were compared with the quantities predicted from the known weight of alcohol burnt, and the results obtained indicate a high degree of accuracy. So satisfactory were these control experiments that it was felt to be necessary to give only one typical experiment and a summary of the results of all experiments of the same type which were made between October 1903 and April 1904 with the calorimeter of 5,000 litres capacity at the Wesleyan University, Middletown, U.S.A. In two of their subjects, A.L.L. and A.H.M., the oxygen intake and the carbon dioxide output, and the heat generated, were simultaneously determined with the subject at rest and in the post-absorptive state at two hourly intervals over periods of eight hours for a number of days. There are 24 sets of determinations for A.L.L. and 21 sets for A.H.M. The 'non-protein' values for oxygen intake and carbon dioxide output and the calories of heat generated were calculated on the usual assumption that the nitrogen excreted during any period corresponds to an amount of protein which has been completely oxidised during that period; if now the oxygen, carbon dioxide and heat (in calories) resulting from this oxidation are deducted from the total figures, the remaining amounts must be solely due to the metabolism of carbohydrate and fat. A recent study which is not yet complete throws some doubt on this method of calculation, particularly for the higher quotients, and no allowance for protein has been made in the later results described in this Address. I have not found that the conclusions are invalidated by this omission.

Using these data for the subjects A.L.L. and A.H.M., the theoretical heat from the oxygen intake and the respiratory quotient was calculated by the Zuntz-Schumburg method, and this heat (indirect heat) was compared with the heat actually measured by the calorimeter (direct heat). The difference between the indirect and direct heat was expressed as a percentage of the direct heat and related to the respiratory quotient by a graphic method. The result is shown in figs. 1 and 2. The horizontal line at zero in the top part of the diagrams represents the condition where the indirect and direct heats are identical; the ordinates represent the percentage differences between the indirect and direct heats. Satisfactory agreement between the heat calculated and the direct heat will depend on the percentage differences, indicated by the black dots, being evenly distributed above and below the horizontal zero line throughout the range of respiratory quotients. This is obviously not the case. The positions of the points suggest a systematic error; for the lower quotients the indirect heat is too high and for the higher quotients too low. The direct and indirect heats only agree at a respiratory quotient of about 0.785 and not elsewhere. At this particular point the respiratory quotient represents a combustion of carbohydrate and fat in the ratio of 1 to 1.36. It is unlikely that there can be a very large error in the first two factors on which the Zuntz-Schumburg values are based (viz. the
heats of combustion of carbohydrate and fat and the chemical composition of these substances), it is therefore in the third factor that we must look for the error; and this must mean that it is not possible to calculate the proportion of carbohydrate to fat actually burnt from other respiratory quotients than 0.785.

When these results were first reported at the Guy's meeting of the Physiological Society in 1932, Prof. Benedict suggested that they might be due to errors in measuring the oxygen. If, for instance, the volume of oxygen was too low, the calculated value for the heat would be too low; at the same time the respiratory quotient would be too high, so that the position of the point would be low down on the right of the diagram and, similarly, if the oxygen were too high the point would be high up and to the left; in fact, the distribution would be the same as in the figures. The oxygen would be particularly liable to error because it was measured both by noting the loss in weight of an oxygen cylinder and also by determining the change in oxygen content of the calorimeter at the beginning and end of the experiment. Any error in the analysis of the gas content of the calorimeter would be magnified in the final result if the volume of the calorimeter was large. On the other hand, the carbon dioxide, which has only a small influence on the indirect heat, was presumably accurate, because as the calorimeter was a closed circuit it could not escape. The validity of this explanation can be tested by noting the
extent of the variation in the volume of oxygen. For A.L.L. the oxygen intake per two hours was 30.1 litres at a respiratory quotient of 0.834 and 20.6 litres at a quotient of 0.932 (a variation of 0.5 litres) and for A.H.M., 29.4 litres at a quotient of 0.762 and 18.9 litres at a quotient of 0.947 (a variation of 10.5 litres). Such variations are surely quite outside any possible error due to analysis. The fact that all control experiments in which alcohol was burnt in the calorimeter show a high degree of accuracy in the measurement of the oxygen intake when compared with the heat output confirms the view that the error indicated in figs. 1 and 2 cannot be accounted for by experimental errors in the measurement of the oxygen.

Similar results have been obtained with a number of individuals who had been observed in the smaller calorimeters at Boston, as well as with a number of pathological cases described by Du Bois and his colleagues, and with Murlin and Lusk’s observations on dogs. We have also shown that they cannot be accounted for by a time lag in the taking up of heat by the calorimeter.

Constancy of Carbon Dioxide Output.—In figs. 1 and 2 the values of the oxygen intake and the carbon dioxide output corresponding to the heat differences have been plotted; the carbon dioxide remains remarkably constant throughout the range of respiratory quotients; the oxygen intake, on the other hand, diminishes as the quotient increases. Benedict and Carpenter comment on the constancy of the carbon dioxide in their experiments. Those authors who have made a number of determinations of the basal metabolism on the same individual have in general obtained a constant CO₂ and a fall in the oxygen with rise of quotient; but when the subject has been taking a carbohydrate diet there is a small but definite rise in CO₂ with rise in quotient and a fall in the oxygen as before.

An Alternative Method of Indirect Calorimetry.

As it became clear that the Zuntz-Schumburg figures could no longer be used for the purpose of calculating the heat generated by the body, the necessity arose of seeing whether any other relationship existed between the oxygen intake, the carbon dioxide output and the heat production from which it would be possible to calculate the heat if the oxygen intake and the carbon dioxide output were known—in other words: Is indirect calorimetry a possibility? To answer this question the plan adopted was to see whether there was any direct relation between the carbon dioxide output and the heat produced, and between the oxygen and the heat. In fig. 3, 337 observations by Du Bois and his colleagues on the basal metabolism have been plotted, and the alcohol control experiments as well. In these metabolism experiments the body temperature was not above 37.5° C. and protein figures are used—i.e. no deduction has been made for the protein metabolism.

The position of the points in the diagrams shows that there is a linear relation between the CO₂ and calories (correlation coefficient 0.950
Fig. 3.—Comparison of indirect and direct calorimetry. Du Bois’s basal values (rectal temperatures not above 37.5°C).

Ordinates: Calories per hour; Abscissae: Upper diagram—CO₂ grm. per hour; Lower diagram O₂ grm. per hour. ◯ Two coincident values. △ Alcohol control experiments.
and mixture. The Cla, and oxygenated fats, and the combustion of the human body. Cathcart and Cuthbertson, were chosen because they represent extremes, and the lines of the other nine human fats analysed by them lie in between. Most of the carbon dioxide points lie between the theoretical carbohydrate and fat lines which are widely spaced; but this is certainly not the case with the oxygen points, as the theoretical limits are much narrower. It is possible to look on the carbon dioxide as the product of combustion of a mixture of carbohydrate and fat, but, because the oxygen points lie for the most part outside the theoretical limits, the oxygen intake cannot be entirely used up in combustion but must in part be concerned in some kind of conversion.

The equation of the regression line to be used for determining the heat from the CO\textsubscript{2} is

\begin{equation}
\text{Calories (per hour)} = 3 \cdot 18\text{CO}_2 \text{ (grm. per hour)} - 4 \cdot 92 \quad . \quad (1)
\end{equation}

THE THEORY OF THE CONSTANT COMBUSTION RATIO.

There is, then, a fundamental error in the theory that the respiratory quotient indicates the proportion of carbohydrate and fat that is being burnt in the body under basal conditions, the theory of the variable combustion ratio; this theory (No. 1) must be abandoned. There are only two other possible theories (Nos. 2 and 3) to be considered. The simplest one (No. 2) is that carbohydrate and fat are always burnt in the body in a fixed proportion, and the respiratory quotient, when it is high, measures the amount of conversion of carbohydrate into some less oxygenated material such as fat, and, when it is low, measures the reverse change.

The other possibility (No. 3), which is more complicated, is intermediate between Nos. 1 and 2. The change in the respiratory quotient is the resultant of two independent variables: a variation in the combustion ratio and a variation in the amount of conversion of one foodstuff towards the other. As the respiratory quotient rises there are two opposed processes of gradually increasing intensity simultaneously at work, one an increasing combustion of carbohydrate relative to fat, which tends to make the heat, calculated by Zuntz-Schumburg, too low, the other an increasing conversion of carbohydrate into fat which tends to make it too high, as it is an endothermic reaction. Against this view there is a fundamental objection. The conversion of carbohydrate and fat may be represented by a reversible equation:

\begin{equation}
4\text{C}_27\text{H}_{50}\text{O}_4 + 42\text{O}_2 \rightleftharpoons 18\text{C}_6\text{H}_{10}\text{O}_5 + 10\text{H}_2\text{O} \quad \text{. \quad (2)}
\end{equation}
which shows that oxygen and not carbon dioxide is concerned with the conversion process. Thus \( \text{CO}_2 \) can only result from oxidation (see also Guy's Hosp. Reports, 85, p. 68); but oxygen has a two-fold function—oxidation and conversion. It has been calculated that the heat of reaction of this equation is 2.1 Cals. per grm. of fat, from which it follows that for every litre of oxygen given out in the conversion of carbohydrate to fat there is an absorption of heat of 3.93 Cals. The oxygen given out in this conversion is used up in the oxidation of carbohydrate and fat, so that a corresponding amount less is taken up from the atmosphere. Equation 2 is based on Cathcart and Cuthbertson's analyses of human fat.

Now 1 litre of \( \text{CO}_2 \), produced in the oxidation of fat, is equivalent to 6.65 Cals. and in the oxidation of glycogen to 5.125 Cals. On an ordinary diet the \( \text{CO}_2 \) output is constant with rise of quotient, and so if there is a rise in the proportion of carbohydrate burnt there must be a fall in the heat of combustion per litre of \( \text{CO}_2 \) with rise of quotient; if there is simultaneously a conversion of carbohydrate to fat there must be a still further fall in the output of heat, as this is an endothermic reaction. But on plotting the measured heat against the respiratory quotient this is not found to be the case: it remains about the same. The only way of expressing this theory to fit the facts is to say that on rise of quotient there is an increasing combustion of carbohydrate relative to fat according to the quotient, and simultaneously a conversion of fat into carbohydrate, which seems absurd, but is really only a roundabout way of expressing theory No. 2. Hence theory No. 3 falls out and No. 2, or the theory of the constant combustion ratio, is left by exclusion.

It must be admitted that this theory is not altogether unreasonable. Many quantities associated with the human body have in health a more or less constant value. The body temperature at rest varies within comparatively small limits, and the same is the case with the hydrogen ion concentration of the blood and the quantity of phosphocreatine broken down in relation to muscular work; while the amount of sleep remains the same for an individual at any particular age. Why should not carbohydrate and fat be burnt in constant proportion in the post-absorptive condition in a normal healthy man. The story of Cain and Abel suggests that the diet of primitive man was variable in its carbohydrate and fat content, depending on his success in cultivation, when it would be mainly carbohydrate, or hunting, when it would be mainly protein and fat. Which is most likely, that the complicated metabolic processes resulting in the actions of the heart, muscles and glands should be entirely at the mercy of the individual's caprice (or luck) in his choice of food, or that these processes should in the main run always along well-defined lines of chemical and physical action, while any foodstuff taken in unusual quantities is stored in some suitable form for future use, even though this means a conversion of some kind? Is it not reasonable to look on these conversions of food as some of the earliest adaptations that the organism has acquired in the course of evolution, and, as Dr. H. E. Magee has
suggested to us this would be a reason for the evolution in the body of the power to manufacture the ferment glutathione, which is otherwise without a clear explanation.

THE MEASURED HEAT AT HIGH AND LOW QUOTIENTS.

If it is assumed that the reaction represented by the reversible equation 2 —carbohydrate to fat conversion—takes place at high and low respiratory quotients while the combustion of carbohydrate and fat in a fixed ratio

![Graph](https://via.placeholder.com/150)

**Fig. 4.**—Comparison of indirect and direct calorimetry on the theory of the constant combustion ratio. Error due to conversion at low and high quotients. Du Bois's results.

Ordinates: Percentage differences between measured heats and heats calculated from CO₂ output. Abscissae: Respiratory quotients.

is taking place simultaneously; the measured (direct) heat should be less than the heat calculated from the carbon dioxide output, by equation 1, at high quotients, since the measured heat will be the resultant of the heat given out from combustion less the heat absorbed in the conversion of carbohydrate to fat. At low respiratory quotients, when the reverse process takes place, the measured heat should be greater than the heat calculated from the carbon dioxide output.

For the construction of fig. 4 the heat was first calculated from the carbon dioxide output for each of Du Bois's 377 observations by the regression equation 1. The difference between the heat calculated in this manner and the corresponding measured heat expressed as a
percentage of the measured heat was then plotted against the respiratory quotient. The principle adopted is similar to that which was used in figs. 1 and 2, where, however, the heat was calculated from the oxygen, using the Zuntz-Schumburg relation.

Here there is a tendency for the percentage differences to be positive when the respiratory quotient exceeds 0.875, for the points do not lie so evenly distributed about the zero line as at intermediate quotients, while below 0.775 they are on the average negative. Hence there is an error in calculating the heat from the carbon dioxide output both at high and low respiratory quotients, an error predicted from theory. This is in contrast to the error, opposite in direction, which appeared when, in figs. 1 and 2, the Zuntz-Schumburg figures were used, and for which there was no explanation on the theory of the variable combustion ratio.

Is it possible to prove quantitatively that conversion of carbohydrate to fat and vice versa does take place at high and low quotients? For this purpose all the observations calculated for hourly periods of Du Bois and his colleagues, apart from diabetes, have been divided into groups according to the quotient, including febrile cases and experiments after food, which fall into line with the figures for the basal metabolisms, though the figures in febrile cases are not so regular as in non-febrile cases; in each group the CO$_2$ and the heat have been correlated and regression equations obtained.

<table>
<thead>
<tr>
<th>R.Q.</th>
<th>No. of hourly observations</th>
<th>Correlation coefficients</th>
<th>Regression Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 0.975</td>
<td>29</td>
<td>0.9715</td>
<td>Cals. = 2.52 CO$_2$ - 0.12</td>
</tr>
<tr>
<td>0.925 - 0.975</td>
<td>45.5</td>
<td>0.924</td>
<td>Cals. = 2.60 CO$_2$ + 1.49</td>
</tr>
<tr>
<td>0.875 - 0.925</td>
<td>86.5</td>
<td>0.879</td>
<td>Cals. = 2.44 CO$_2$ + 7.13</td>
</tr>
<tr>
<td>0.825 - 0.875</td>
<td>184.6</td>
<td>0.9355</td>
<td>Cals. = 3.055 CO$_2$ - 3.87</td>
</tr>
<tr>
<td>0.775 - 0.825</td>
<td>345.9</td>
<td>0.918</td>
<td>Cals. = 3.043 CO$_2$ - 1.63</td>
</tr>
<tr>
<td>0.725 - 0.775</td>
<td>159</td>
<td>0.91</td>
<td>Cals. = 2.68 CO$_2$ + 9.85</td>
</tr>
</tbody>
</table>

Equations 6 and 7 are very similar to one another, and it would be reasonable as an approximation to take the average—

\[
\text{Cals.} = 3.049\text{CO}_2 - 2.75
\]

and to call this the regression equation at the intermediate quotient 0.825. If we assume, as is compatible with fig. 4, that at this quotient a mixture of carbohydrate and fat is burnt and there is no conversion, it will be possible to calculate for the conversion process at high and low quotients the calories absorbed or liberated per litre of oxygen liberated or absorbed and to see how this agrees with the theoretical value from equation 2, viz. 3.93 Cals. per litre. The method of calculation is as follows: For 25 grms. CO$_2$ (12.7 litres) at R.Q. = 0.825, the O$_2$ is 15.4 litres, and the heat from equation 9 is 73.48 Cals. For 25 grms. CO$_2$ at R.Q. = 1, the O$_2$ is 12.7 litres, and the heat from equation 3 is 62.68 Cals. Hence at
this quotient there is 10.6 Cals. less heat given out and 2.7 litres less O₂ absorbed; or 3.93 Cals. per litre O₂.

The following calculations have been made:

<table>
<thead>
<tr>
<th>CO₂ grams per hour</th>
<th>15</th>
<th>25</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.Q. 0.75 Cals. liberated per litre oxygen absorbed</td>
<td>7.6</td>
<td>2.18</td>
<td>—</td>
</tr>
<tr>
<td>&quot; 0.90 Cals. absorbed per litre oxygen liberated</td>
<td>—</td>
<td>3.7</td>
<td>5.75</td>
</tr>
<tr>
<td>&quot; 0.95 &quot;</td>
<td>4.0</td>
<td>3.45</td>
<td>2.03</td>
</tr>
<tr>
<td>&quot; 1.00 &quot;</td>
<td>3.27</td>
<td>3.93</td>
<td>4.14</td>
</tr>
</tbody>
</table>

The figures for the Cals. per litre of oxygen are of the same order as the theoretical figure 3.93, and the equations 3 and 4 for R.Qs. 0.95 and 1.00, where there is the largest amount of conversion, give the closest figures. The other two equations 5 and 8 give at one point an impossible figure, indicating absorption of heat when there should have been liberation, and vice versa. But the figures are provisional. The R.Qs. chosen for calculation are not the averages, or the medians of the R.Qs. in the groups, and it appears now that determinations in diabetes should be added. But considering that the figures represent the ratio of differences between quantities ten times as large, and so are particularly liable to error they do seem compatible with the conversion of carbohydrate and fat at high and low quotients, and in this sense provide a quantitative proof.

Food.—I have just said that the values for the CO₂-heat relation after food fall into line with the basal metabolism results when grouped according to the respiratory quotient. This has implications of interest, because most results in the groups belonging to the higher quotients were obtained after food, and particularly carbohydrate. Hence, conversion into fat takes place within the first few hours after ingestion of carbohydrate, and the resulting absorption of heat explains the well-known small specific dynamic action of carbohydrate. After ingestion of fat the specific dynamic action is also small, but this is because the values remain at the basal level without alteration of quotient, presumably because fat delays the emptying of the stomach. On the other hand, after protein there is eventually increase both in the heat and the respiratory exchange—hence the high specific dynamic action; but in the first hour or two there is often a rise of quotient and little if any increase of heat, which makes it probable that any rate part of the protein is immediately converted into fat, and in this case invalidates the usual method of calculating non-protein metabolism.

**Muscular Work.**

Investigating the effect of diet on the respiratory exchange due to muscular work, Krogh and Lindhard found that with carbohydrate more CO₂ was excreted and less O₂ was absorbed than with a diet mainly of fat. On the theory of the variable combustion ratio this meant that less heat was produced with carbohydrate, so that the body worked more economically. Benedict and Milner² have made the only systematic investigation

of muscular work in a respiratory calorimeter; but their results were published thirty years ago and seem to have been overlooked. They found that for the same amount of work the heat output was practically the same on a mixed diet containing roughly equal proportions of carbohydrate and fat as on a carbohydrate diet. Comparing the best two experiments when equal amounts of work were accomplished—63 and 62 on A.L.L.—the total heat output for 3 days was 14670·1 and 14464·4 Calories respectively, a decrease on the carbohydrate diet of only 1·4 per cent. The CO$_2$ values were 1298·4 and 1397 grms. and the oxygen values were 4317·2 and 4058·3 grms.; these differences are like those that Krogh and Lindhard subsequently found; the R.Q's. were 0·802 and 0·896. The results cannot be explained on the older theory because the heat remained nearly the same on the two diets; but on the theory of the constant combustion ratio, because the CO$_2$ was increased on the carbohydrate diet, the combustion of the normal carbohydrate-fat mixture must have been increased and more heat produced; this increase of heat must have been neutralised by the heat absorbed in the conversion of carbohydrate to fat, a process that, must have occurred, because less oxygen was absorbed on the carbohydrate diet.

To obtain quantitative evidence of this conversion regression equations of the heat—CO$_2$ and O$_2$—heat relations for A.L.L. on the two diets have been calculated for 6 hourly periods in all experiments, omitting the first periods in Experiments 62, 63 and 65, which were transition periods as regards diet, but adding the basal determinations in Carnegie Inst. Publication 261 to the mixed diets; CO$_2$ and O$_2$ are expressed in grms.:

**Mixed diet:**
\[ \text{Cals.} = 2·94 \text{CO}_2 + 45·1 \]  
\[ \text{O}_2 = 0·303 \text{Cals.} - 10·1 \]

**Carbohydrate diet:**
\[ \text{Cals.} = 2·71 \text{CO}_2 + 42·5 \]  
\[ \text{O}_2 = 0·288 \text{Cals.} - 0·4 \]

Suppose 400 grms. CO$_2$ is excreted on the mixed and on the carbohydrate diets the calories from equations 10 and 12 are 1221 and 1128, i.e. with less muscular work there were 93 less calories given out on the carbohydrate diet. From equations 11 and 13 the oxygens corresponding to these heats are 359·5 and 324·6 grms.—i.e. 34·9 grms. less oxygen was absorbed on the carbohydrate diet; on passing from the mixed to the carbohydrate diet the heat absorbed per grm. of oxygen was

\[ \frac{93}{34·9} = 2·66 \text{Cals.}, \text{or} 2·66 \frac{32}{22·4} = 3·8 \text{Cals. per litre of oxygen}; \text{now the theoretical value for the conversion of carbohydrate to fat is 3·93.} \]

Similar calculations over the range of CO$_2$'s obtained in the muscular work and following rest period gave results as follows:

<table>
<thead>
<tr>
<th>CO$_2$ grm. per 6 hours</th>
<th>250, 400, 600, 700</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat absorbed in conversion, Cals. per 6 hours</td>
<td>59·6, 93, 138, 166</td>
</tr>
<tr>
<td>Cals. per litre of O$_2$ absorbed in conversion</td>
<td>7·48, 3·8, 3·44, 3·38</td>
</tr>
</tbody>
</table>

At any rate the experimental figures are of the same order as the theoretical figure 3·93.
Another method of calculation depends on using equation 7 in comparing Experiments 63 and 62. With carbohydrate there was excreted 361.4 grms. $\text{CO}_2$ more than on the mixed diet. If this resulted from oxidation of a carbohydrate-fat mixture at R.Q. 0.802, the heat would be by equation 7, 1097.4 Cals. Hence $14670 \frac{1}{1} + 1097.4 - 14464.4 \quad (= 1303.1)$ Cals. must have been absorbed on changing to the carbohydrate diet, owing to conversion. Since 44 grms. $\text{CO}_2$ requires 32 grms. $\text{O}_2$ for its formation, the oxygen required to produce 361.4 grms. $\text{CO}_2$ at the R.Q. would have been $\frac{361.4 \times 32}{44 \times 0.802} \quad (= 327.7)$ grms. The oxygen that must have been absorbed on changing to the carbohydrate diet was $4317.2 + 327.7 - 4158.6 \quad (= 486.3)$ grms. Hence the calories absorbed per grm. of oxygen was $\frac{1303.1}{486.3} = 2.679, \quad \text{or} \quad 2.679 \frac{32}{22.4} \quad (= 3.83)$ Cals. per litre. This value, 3.83, is very close to the theoretical value 3.93.

Thus, there is every probability that carbohydrate is converted into fat in muscular work on a carbohydrate diet. This may explain the quotients above unity obtained by C. H. Best, K. Furusawa and J. R. Ridout. A point of interest is that the amount of the conversion increases with the muscular work and the total respiratory exchange, which suggests that conversion and combustion are linked reactions.

Teleologically, the value of a conversion of carbohydrate to fat may be questioned, considering the enormous storage of fat in the body compared to carbohydrate; but these deposits of fat may not be readily available, and anyhow a better way of looking at the conversion process is from the point of view of a velocity reaction, the amount of conversion depending on the concentration of carbohydrate in the reacting tissues, which is increased on a high carbohydrate diet. The interesting conclusion may be drawn that muscular work on any diet produces nearly the same amount of heat; if heat is absorbed in conversion from carbohydrate to fat this must be provided by increased combustion of the standard carbohydrate-fat mixture.

A New Definition of Basal Metabolism.

On the theory of indirect colorimetry, based on the constant combustion ratio of carbohydrate and fat, the non-protein carbon dioxide results entirely from the combustion of carbohydrate and fat, while the oxygen is used partly for combustion and partly in conversion processes. If the respiratory quotient is high, say 0.9, the heat, calculated on the assumption that the oxygen is used entirely for combustion, is about 8 per cent. above the heat actually found, because the heat due to combustion is diminished by the heat absorbed in the conversion of carbohydrate towards fat (see fig. 4). Since under basal conditions there are continual small variations in the quotient, there will be continual additions to or subtractions from the heat of combustion, according as the conversion of fat to

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carbohydrate is taking place or *vice versa*. Since these conversions are ephemeral and will cancel each other over a long period, they can hardly be regarded as part of a 'standard' metabolism, and so it is much better to neglect them, and this is done by taking the carbon dioxide alone into consideration. In these circumstances the basal or standard metabolism must be defined afresh as the heat of combustion at rest in the post-absorptive state and not as the total heat measured in a calorimeter, the value of which may be a little different, depending on the respiratory quotient. If this definition be accepted it follows that the carbon dioxide alone must be measured and no account must be taken of the intake of oxygen.

**Standards of Metabolism, Growth, and General Nutrition in Children.**

In working out a new standard of basal metabolism from the CO₂ it was decided, as Benedict has done, to determine the mathematical correlation between the four quantities, carbon dioxide excretion, body weight, height, and age, irrespective of any preconceived theory that might possibly relate them together; but, as in Meeh's and Dreyer's formulae and in the height-weight formula of Du Bois, the Calories were related to a power of the body weight, it seemed advisable as a first step to plot the logarithms of the body weight and carbon dioxide output with a view to determining graphically what the power was. This was a fortunate step as, in the case of the children, it at once indicated that between 1–2 and 4–5 years of age there was a break in the continuity of the curve relating these quantities; further work showed a closer correlation between CO₂ and height up to 5–6 years of age than between CO₂ and weight, since some children were unusually heavy, possibly from retention of fluid associated with hypothyroidism. At these ages height is the best measure of metabolism. As the baby grows from birth to a height of 29 in., i.e. up to 1 year, the regression equation is as follows:

Early infancy:

\[ \log \text{CO}_2 = 3 \cdot 15 \log \text{height} - 4 \cdot 04 \]  
\[ \text{(14)} \]

Between 29 in. (1 year) and 41½ in. (5–6 years) it is

\[ \log \text{CO}_2 = 0 \cdot 46 \log \text{height} + 1 \]  
\[ \text{(15)} \]

In other words, there is but little increase in CO₂ with growth between heights of 29 and 41½ in.; subsequently up to about puberty there is again a larger increase in the CO₂ output, and it is now higher for boys than for girls. These CO₂ values of Benedict and Talbot are probably on the low side, though they are consistent in themselves; but the recent results of R. C. Lewis⁴ and others will have to be investigated in order to obtain a more correct prediction of the CO₂ from the height or weight of children above 5 to 6 years.

The suggested explanation of the kink at 29 in. is the exercise taken by the child when he or she begins at first to crawl and later to run about; these activities burn up fat and consequently the luxus consumption associated with the fat storage and over-nutrition of babyhood disappears, which means that the higher carbon dioxide production in proportion to body weight becomes lessened. On this view the baby in early infancy leads a vegetable existence, absorbing nutriment without much activity; above one year old he gradually becomes an energetic child. If this is true, there should be a kink in the reverse direction when the logarithms of the height and body weight are plotted against one another, because at this point the baby would increase in height but not correspondingly in weight as the nutrition became lower; this was found to be the case and there was a second kink at $41\frac{1}{2}$ in. (between 5 and 6 years), which also coincided with and explained the change in the log. CO$_2$-log. weight relation at this height. There are, thus, 3 nutritional periods in postnatal life; during the first the child puts on fat, and both the body weight and the metabolism increase rapidly as the result and luxus consumption becomes established. (There is also luxus consumption in the exogenous obesity of adults); in the second period with the loss of fat the increase in body weight is less, while the metabolism remains almost stationary; in the third period the increase in body weight and metabolism with growth is again established, but in neither is the increase as rapid as in the first period, since there is not the same amount of fat deposited.

Emphasis has been laid on height rather than age or weight in determining the metabolism of an infant, and this suggests that the other landmarks of development, such as the eruption of teeth, power to lift the head, closure of the fontanelle, should also be related primarily to height.

**Example (2 first cousins).**

1. First tooth at 27 weeks 22 lb. 27$\frac{3}{4}$ in.
2. ,, ,, 37 ,, 16$\frac{3}{4}$ ,, 28 ,, 

Dr. H. St. J. Vertue, who is kindly making observations at the Salamon Centre, Guy's Hospital, writes: 'Up to the present my figures (for eruptions of first teeth) do show a wide disparity of age and weight and not much disparity of length.'

These three nutritional periods of childhood with their varying effect on body weight suggest that the relation of body weight to age would not be a satisfactory measure of growth, and this is borne out by the S-shaped curve (unique for man) that is obtained when weight and age from birth to puberty are plotted against one another. A much simpler curve is obtained when height and age are related; this is the 'cumulative growth curve.' Above 6 years it is roughly linear till near puberty, when there is an increase in growth, forming the so-called prepubertal rise. Such curves (and they can be drawn back into prenatal life) are the best measure of growth, and they demonstrate that on the average children are taller than they were 56 years ago, and that children from better-class
families are taller than from poorer families. On the other hand, the relation of log. height to log. weight, which we and others have regarded as the best index of 'general nutrition,' is on the average the same now as it was 56 years ago, and is identical for all classes of the community. Both these facts have been pointed out before; but it does not appear that their combination has been sufficiently emphasised. There is some factor in modern life that tends to promote growth in the children of the wealthier classes; this was missing 50 years ago and is still missing among the poorer classes to-day. But though wealth tends to produce giants and poverty dwarfs, both giants and dwarfs are equally well formed; their general nutrition remains the same. Heredity is certainly a factor in promoting tallness or shortness; but it is impossible to imagine that the wealthy have unconsciously selected themselves for tallness during recent years. There must be other factors and improvement of the food supply with abundance of minerals and vitamins are obvious ones; this subject has been dealt with by Orr. In this connection observations by Brody and others on animal nutrition are of great interest. The weight and chest girth of steers are greater for a given age when the animal is full fed than when it is scantily fed; but the height at withers is the same in the two cases. This is the reverse of the findings in children. The steers were equally tall but the poorly fed were thinner; so their general nutrition was poor.

The explanation may be as follows: In poorly fed steers the amount of food was apparently cut down and therefore the Calories were deficient, but the diet remained qualitatively the same, so that the growth factors were adequate. On the other hand, according to Orr's observations, the intake of vitamins, of calcium, phosphorus and iron is deficient among the poorer classes of the community and is proportional to the amount spent on food, which itself depends on the income of the family. These are all growth-promoting factors. The intake of Calories is only deficient in the poorest group where the income is up to 10s. a week per head, and of this 4s. per head is spent on food. It is permissible to doubt whether the Calories are really deficient in this group, considering the small size of the individuals and the difficulty in estimating how many Calories are required to keep up bodily nutrition—a subject which has been touched on elsewhere. At any rate Elderton's measurements of Glasgow children show that there is no marked difference between the log. height/log. weight relationship for the richest and poorest classes of the community; but the poorer children are shorter and lighter for their age than those from better-class families, and the different classes of society have been graded, as far as their wealth is concerned, by their tallness. It is reasonable to assume that the main deficiency is in the growth factors and not in the total amount of Calories. It does not follow that the small, short individual with a normal general nutrition is a less perfect physiological organism than the individual who is tall. In certain walks of life tallness

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may be a disadvantage. In a famine the short, light individual would certainly require less food.

**STANDARDS OF METABOLISM IN ADULTS.**

Is there any advantage in taking height into consideration in addition to weight and age, in calculating the basal metabolism of adults? To answer this question two equations have been derived from the same series of published data for men.

Log. carbon dioxide

\[ \log \text{carbon dioxide} = 0.6204 \log \text{body weight} - 0.00357 \text{age} + 1.3015 \quad (16) \]

Log. carbon dioxide

\[ \log \text{carbon dioxide} = 0.51208 \log \text{body weight} + 0.5389 \log \text{height} - 0.00357 \text{age} + 0.2573 \quad (17) \]

The carbon dioxide is in c.c.s. per minute, body weight in kilograms, height in centimetres, age in years between 15 and 35.

<table>
<thead>
<tr>
<th>Body Weights.</th>
<th>Number of subjects</th>
<th>Number which best fit.</th>
<th>Standard deviation of the differences between calculated and measured CO₂.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within ± 10% of average body weight for height</td>
<td>127⁵</td>
<td>55</td>
<td>70</td>
</tr>
<tr>
<td>Between ± 10% and ± 20% of average body weight for height</td>
<td>38</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>Beyond ± 20% of average body weight for height</td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

The CO₂ calculated from the two equations is then compared with the actual CO₂ measured. For this purpose all the observations have been separated in the table into 3 categories, according as the body weight lay between ± 10 per cent. and - 10 per cent. of the average body weight for the height, between ± 10 per cent. and ± 20 per cent. and beyond

⁵ In two cases both equations were equally good.
20 per cent. In column 2 is given the number of subjects in each category, and in columns 3 and 4 the number of cases in which equation 16 or 17 respectively gave a result closer to the carbon dioxide found experimentally. The meaning of the figures in the last two columns in this table may be expressed as follows: Suppose 200 c.c. CO₂ are excreted per min., then since 90 per cent. of observations probably fall within 1.611 times the standard deviation (Pearl), we may assume that for the 127 subjects in the top line 90 per cent. of values calculated by equation 16 would probably lie between 176.7 and 223.3 c.c., while the corresponding limits for equation 17 would be 177.3 and 222.7 c.c. It is clear from these figures that the variation between the two equations is negligible, and so it may be argued that it is more physiological to use equation 16, which involves only body weight and age, because, if height is really important, the improvement with equation 17 should be more marked. Although in this particular series of results from which both equations were derived equation 17 gives for mathematical reasons slightly closer results, it does not follow that this would be the case if these equations were applied to another series of normal individuals. Hence equation 16 which involves fewer measurements has been retained as the chosen prediction equation.

Effect of Sex and Age on Basal Metabolism.—From 5 or 6 years onwards girls have a lower basal metabolism for their weight than have boys. The differentiation of the sexes as regards their metabolism, which begins after the erect posture is attained and exercise is being freely taken, is of great interest, as it appears long before any secondary sexual characters. It is possibly due to the fact that from about 5 to 6 years onwards girls on the whole take less exercise than boys and consequently their muscles are less developed and so the basal metabolism which must largely depend on muscular development is lower. Athletes have a higher metabolism than ordinary men. In babyhood there is no noticeable difference in activity between the sexes and their basal metabolisms are the same. From puberty onwards the difference in activity is marked and the difference between the metabolisms is at a maximum. We have suggested that the falling off of metabolism with age is also due to lessening muscular activity with consequent muscular atrophy; this takes place more rapidly in men than women, and this would agree with the more rapid drop of the metabolism in men. It would be of particular interest to compare the metabolisms of very old men and women; on this hypothesis they should be the same, since muscular activity in both would be at a minimum.

Practical Indirect Calorimetry.

I use the ‘open’ method of Krogh and Lindhard for determining the carbon dioxide in clinical work. Fresh outside air is supplied to the subject by a mask and valves; from the subject the expired air passes to the bottom of a wide-mouthed bottle of about 2 litres capacity, which in
order to improve the mixing may contain two horizontal layers of copper gauze, one just above the opening of the delivery tube and the second towards the top of the bottle below the exit tube. Samples of the mixed air as it leaves the bottle are analysed every five minutes by means of a Haldane gas analysis apparatus fitted with a 10 c.c. burette (a 30 c.c. burette has recently been used), connected to the bottle by means of lead tubing of fine bore. The expired air then passes to a large gas meter measuring 15 litres per revolution, which is read every five minutes. A rubber anaesthetic bag is connected by means of a T-piece to the tube between the bottle and the meter. With a large meter and bag in circuit there is no perceptible resistance to ordinary breathing, and the valves have been constructed with the same end in view. They consist of Paul’s rubber intestinal tubing split longitudinally along both edges and clipped at intervals of about an inch with clips. Dr. Alice E. B. Harding, who has used the method for children, has found that a practical method of testing for leaks between the face and the mask is to hold a polished metal spatula near the junction; if expired air escapes the surface of the metal is dimmed by the deposition of moisture. Five consecutive experiments are given in the table. They were usually continued for 25 minutes or half an hour, though a shorter period might sometimes be enough. Contrary to the general impression the carbon dioxide after the first five or ten minutes gives very constant results, if the patient is quiet and comfortable. An increase towards the end of the period can usually be accounted for by some extraneous factor, such as shivering or restlessness. There is no necessity for the examination to be restricted to the nursing home or hospital; but the patient should be advised to do the minimum of walking on the morning of the test. Most of the original experiments were carried out under these conditions.

The advantage of this method is that the constancy of the breathing and metabolism throughout the period can be assessed; its disadvantage is that the total volume of expired air is not collected before taking out

<table>
<thead>
<tr>
<th>T.R.H.</th>
<th>O.T.</th>
<th>K.W.</th>
<th>F.M.T.</th>
<th>A.E.B.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ %</td>
<td>CO₂ c.c. per min.</td>
<td>CO₂ %</td>
<td>CO₂ c.c. per min.</td>
<td>CO₂ %</td>
</tr>
<tr>
<td>3.75</td>
<td>213</td>
<td>4.29</td>
<td>243</td>
<td>3.47</td>
</tr>
<tr>
<td>3.91</td>
<td>218</td>
<td>4.29</td>
<td>241</td>
<td>3.42</td>
</tr>
<tr>
<td>3.83</td>
<td>212.5</td>
<td>4.30</td>
<td>237</td>
<td>3.42</td>
</tr>
<tr>
<td>3.55</td>
<td>214</td>
<td>4.33</td>
<td>240</td>
<td>3.56</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>3.39</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>3.46</td>
</tr>
</tbody>
</table>
a sample for analysis; but this will not matter provided the breathing
remains constant, as indicated by the series of observations. This diffi-
culty can be overcome by using two analysis apparatuses; in one the
analysis is made, while in the other air is gradually being collected in the
burette during the five minutes by allowing the mercury to fall slowly;
this is analysed, while a further sample is being collected in the first
apparatus, and so on; alternatively the air could be collected in sampling
tubes and analysed later.

Finally, I should like to thank Mr. T. W. Adams, who has been
associated with me in the calculations on which these results are based,
and Mr. W. J. Martin of the London School of Hygiene for advice on
the mathematics required, and to express my indebtedness to the Parsons
Fund at Guy's Hospital and the Medical Research Council for grants in
aid of the work, and to the Physiological Society and Guy's Hospital Reports
for the illustrations. This study is not yet complete, though I think the
main conclusions will stand. We hope in due time to publish all the
evidence on which these conclusions are based.
Tests for colour vision fall into two categories. In the one type of test, transmitted light is used, in the other reflected light. While the former type of test is regarded as the more fundamental, the latter can be of great service for quick diagnosis of colour anomaly. Colour tests may be administered purely for theoretical purposes, or they may be applied for practical purposes, as selection tests for different vocations. This second function assumes its most important rôle in vocations in which lack of accurate discrimination between different coloured signals may involve human lives. This function is also of significance in other vocations in which the lack of colour discrimination, though not involving danger to the community, is highly disadvantageous to its possessor.

These two aims, though not mutually exclusive, it is better to keep clearly in mind in any discussion. The results of certain tests may be invaluable for theoretical purposes, although for practical purposes their value may be negligible. This confusion of the two aims has probably been partly responsible for the production of the many differences of opinion which have been expressed with regard to the commoner tests at present used for diagnosis.

There seems to be no need at the present day to emphasise the importance of the recognition and detection of colour defect. It is, however, very illuminating to study some of the more recent investigations in the field, particularly those concerned with the incidence of red-green defect. The percentages given seem to be much higher than in the reports of the earlier investigations. It does not necessarily follow that the incidence of the defect is increasing; the indications are rather that detection is more accurate owing to the improvement of the test material. The figures given in previous estimates are generally somewhere in the region of 3 or 4 per cent. so far as the male population is concerned. While some of the percentages quoted during the past few years are still in this vicinity, it is not unusual to find a number of considerably higher percentages recorded also. Waaler, who tested 9,000 persons, found a frequency of 8.01 per cent. in the male sex; Planta testing

2 Ibid.
2,000 boys, a frequency of 7.95 per cent. Kilborn and Beh, testing
Chinese male students, found 6.3 per cent. of them to be red-green
blind, and Hsiao, examining Chinese children, gives his figure as
5.57 per cent. among the boys. Lorenzo and McClure found, of a
group of men tested at the University of Toledo, that 9 per cent. were
colour blind, and Garth, testing children and students in Turkey, a
percentage of 5.3. Among groups of medical students, Macklin found
about 11.0 per cent., and Tocantin and Jones found 12.8 per cent.
who were red-green colour blind. Miles testing university men,
gives 8.4 per cent. as colour blind, and among a group of dry goods
salesmen he found a percentage of 7.2. Out of 360 candidates applying
for acceptance as apprentice printers, examined by the present writer,
the percentage of red-green colour blinds was 7.5, this figure being
exclusive of the colour weak and the anomalous.

At the present day, there are said to exist three varieties of colour
blindness. And while we are primarily concerned with the red-green
variety only, it seems desirable for completeness to indicate briefly the
nature of the other two types. They are not of equal importance either
from a theoretical or from a practical point of view.

Total colour blindness or Achromatopsia (sometimes called Achroma-
topia) is not of frequent occurrence, only about eighty cases having been
described up to date. To the totally colour blind the spectrum is a
colourless band, differing only in luminosity. Red may appear black,
orange dark grey, yellow light grey and so on. To such a monochromat
bright light is extremely dazzling, in fact, ordinary illumination is some-
times unbearable. but in dim illumination he can see fairly accurately.
Achromatopsia is often accompanied by nystagmus and by poor central
vision. In many cases an absolute central scotoma exists which means
absolute blindness to light at the fovea as well as to colour. Parsons
states that 'whether all cases have an absolute central scotoma or not,
it is certain that foveal vision is very defective, even as compared with
parafoveal, as is admitted by Hess.'

To the totally colour blind the region of maximal brightness lies in
the green, a condition similar to that found in the dark-adapted or
scotopic eye. The luminosity curve of the monochromat agrees very
closely with the normal achromatic scotopic luminosity curve. There

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3 Science, 1934, 79, 34.
5 Ibid., 320-330.
6 Science, 1936, 84, 85.
8 Amer. J. Med. Sci., 1933, 185, 243-249.
9 The Personnel J., 1931, 9, 437-449.
10 For a description of a case of total colour blindness, see Snyder, Amer. J.
Psy., 1929, 41, 398-411.
11 This term is objected to by E. Murray, who writes: 'Monochromatic is merely
a physicist's tag signifying that in this type of deficiency any wave-length of light
can be matched against any other. Actually the vision of the subject is achro-
matic, without any colour quality whatsoever. No genuine monochromasy in
the descriptive sense is, for theoretical reasons the compounding of white from
chromas, admissible.' Quoted from article in Amer. J. Psy., 1930, 42, 117-127.
Color Problems: the Divergent Outlook of Physicist and Psychologist.
12 'An Introduction to the Study of Colour Vision,' 2nd Ed., p. 199.
may also exist a form of monochromatism in which the visibility curve is of the light-adapted or photopic type.\(^{13}\)

The second variety of colour blindness, which has little practical significance, although it has considerable theoretical importance, is that of blue-yellow blindness, in which the ability to see blue and yellow is affected, but the ability to see red and green is unaffected. This second type is of doubtful existence as a congenital condition, although one or two apparently authentic cases have been recorded. Generally, it is accompanied by some pathological change in the eye. One case, reported by Richardson, saw blue as a dazzling white.

Parsons\(^{14}\) points out that 'it is simulated in cases of jaundice and sclerosis of the crystalline lens, these being due to absorption by yellow pigment.' Abney\(^{15}\) and Hess\(^{16}\) have found that the same defect may arise in cases where the pigmentation of the macula is unusually dense.

This second form of colour blindness has been termed violet-blindness by the adherents of the Young-Helmholtz theory, or as Maxwell preferred to term it, blue-blindness. The followers of the Hering theory describe the defect as blue-yellow blindness. The term, tritanopia, was suggested by v. Kries.

The third form of colour blindness, red-green blindness, is the most important of all, because of the frequency with which it occurs, as has been already observed, and because of the colours which are confused. The defect is congenital and hereditary. It occurs on the male side of a family, and is practically non-existent on the female side, only about 1 in 500 being colour-blind. A female, however, whose father is colour-blind, may transmit the defect to her sons. In other words, it may pass over a generation, remaining latent in the female, but reappear in the next generation on the male side.\(^{17}\)

Two forms of this colour defect are recognised, depending on whether the spectrum is of normal length or shortened. These are described as green-blind and red-blind respectively by the adherents of the Helmholtz theory: as red-green blind by the exponents of the Hering theory, the difference in the two types being ascribed to differences in macular pigmentation. The names deuteranopia and protanopia, suggested by v. Kries, are used independently of any colour theory. The terms photerythrous (visibility of the red) and scoterythrous (darkness of the red) put forward by Rivers, have unfortunately never been adopted.

It seems more or less agreed that red-green colour blindness is a reduction system of normal colour vision, one cogent argument in support of this contention being that normal colour matches are valid for any type of dichromate. The colour blinds lack something which the normal eye has, but have nothing which the normal eye does not possess. The individual with normal colour vision sees a spectrum composed of six

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\(^{13}\) See Chapter 13 by Troland in *A Handbook of General Experimental Psychology*, 1934. Edited by Murchison.

\(^{14}\) Ibid., p. 192.

\(^{15}\) Arch. f. Anat., 1908, 61.


\(^{17}\) Colour blindness may also be acquired, but it is not necessary to discuss this form of colour blindness here.
or seven colours. The red-green colour blind has a spectrum composed of only two colours, these two colours being yellow and blue. The acceptance of this fact was delayed for a long time, and it is doubtful if it is yet generally accepted. Herschel in 1845 was the first to put forward the dichromic explanation of colour blindness. He pointed out in his article on 'Light' in the *Encyclopedia Metropolitana* that certain individuals could only distinguish two colours, and that these two colours were yellow and blue. Clerk-Maxwell, among others, opposed this, for he accepted the theory put forward at that time by Young and Helmholtz that colour blinds were either red-blind, green-blind or violet-blind, and that the red-blind were blind to red, but could see the remaining two colours, green and violet: the green-blind were blind to green, but could see red and violet.

In an account by Pole of his own case,\(^{18}\) we find he vigorously protests against these prevailing beliefs, and gives a careful analysis of his own colour vision as evidence. He had been pronounced red-blind by Maxwell and green-blind by Holmgren. Pole repudiated both suggestions, and claimed that the true solution was that he was blind to both colours. This conclusion was confirmed by a large number of facts. One was the evidence of the colour blinds themselves who, whether they were classified as red-blind or green-blind, asserted that their colour sense was composed of blue and yellow. Another was a case of congenital unilateral dichromatism investigated by von Hippel in 1880. The individual tested had normal colour vision in his left eye but was colour blind in his right eye. With the right eye he confused red and green with yellow, as tested by various standard tests. The colours which the subject could distinguish with his right eye were blue and yellow, these being confirmed when he looked at them with his normal eye. Von Hippel diagnosed the case as one of red-green blindness with spectrum of normal length. Holmgren examined the case with his wool test and proclaimed it to be one of red-blindness with shortened spectrum in accordance with the Helmholtz theory. Von Hippel retested his subject and reaffirmed his first finding. This was the first case of monocular colour vision reported, and it undoubtedly strengthened the case for the acceptance of Herschel’s and Pole’s views. Holmgren, it is interesting to note, ultimately agreed that blue and yellow were the only colours seen. That this point is still controversial may be gathered from the statement made by Pitt\(^ {19}\) in a recent investigation, that the fundamental responses of the protanope are blue and a saturated green, while those of the deuteranope are blue and a mixture of red and green.

Only a few cases of unilateral colour blindness have been recorded, and these, according to Parsons, are of ‘doubtful value.’ In these cases, however, the suggestion is always that the colours seen are blue and yellow. Miles and Beaumont,\(^ {20}\) who tested the two eyes separately in

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an investigation into colour blindness, found considerable difference between the two eyes in many cases, and suggest that although there is no conclusive evidence as to the frequency of unilateral colour blindness, that 'possibly it amounts to three or four per cent. of the colour blind.' They discovered one such case in a group of 23, and Miles and Craig found another in a group of 390 mercantile salesmen.21 This latter individual was a dry goods salesman and aware of his condition, and if required to match fabrics he closed the defective eye and made the proper discrimination with his normal eye. If these cases of unilateral colour blindness are as numerous as suggested, a field seems opened up for further investigation which may lead to definite conclusions as regards the fundamental sensations of the red-green colour blind.

The results of investigations carried out over a number of years at Edinburgh into the colour sensations of the red-green colour blind, seem to indicate that their colour sensations are indeed blue and yellow.22 The extent to which these two colours replace all the other colours in the spectrum is, however, not constant for every colour blind. With some, yellow and blue may replace all the other colours, that is, red, orange, yellow and green may be seen as different shades of yellow, blue and violet as different shades of blue. Sometimes, instead of the green being replaced by yellow, it may appear as grey, or the blue-green may appear as grey, the extent of the neutral band varying with the gravity of the defect. A second neutral band is also found extra-spectrally in the complementary colour, in the purples.

In one extreme case which came under observation, only two narrow bands of yellow and blue existed, the other colours being seen as shades of grey. Red appeared as black, orange as dark grey, yellow could be discriminated, green and blue-green were seen as grey, blue could be distinguished, but violet appeared as dark grey. In one test, out of 76 colours observed, 64 of them appeared as grey.

All cases, however, are not so extreme as the one just described and the general finding which seems to be gradually gaining ground, is that there exist different degrees of colour blindness extending from extreme cases in which blue and yellow are the only two colours visible to milder cases in which the blindness to red and green is not total. In these milder cases the individual can see red and green if they are bright enough or vivid enough. It is these milder forms which constitute the great practical problem, for in these cases the ability to distinguish between red and green is likely to fail when the individuals are fatigued, or when the illumination is poor, as in mist or fog. The extreme cases can be easily detected, but the milder cases, which have been described as 'dangerous colour-blinds,' require very careful examination if they are to be detected.

That different degrees of colour blindness exist has been emphasised by more than one writer. Hayes 23 wonders if we shall presently have

22 Collins: Colour Blindness.
to give up all classifications by types, arrange colour defectives in distribution tables and give a colour graph or profile for each subject, showing his efficiency or deficiency for each colour in terms of a per cent. of the normal or average attainment.' Troland states that the original restriction of colour blinds to protanopes, deuteranopes and tritanopes is not adequate any longer, and allowances must now be made for more types of variation. Edridge-Green recognises seven different types of colour vision, and Schjelderup states that there are at least eighteen significant species of colour blindness. Collins reaches the conclusion that it is quite unprofitable to try to classify the colour systems of the colour blind because there exist so many individual variations.

One group in which the colour defect is not extreme has been definitely recognised. Seebeck, in 1837, found certain cases which he was reluctant to classify as colour blinds, who yet showed signs of colour abnormality. It was not until 1881, however, that these cases were understood. In that year, Rayleigh found that a number of individuals with otherwise normal colour vision were unequally sensitive to red and green. In equating red (lithium line 670 µm) and green (thallium line 535 µm) to match a yellow (sodium line 589 µm), since known as the Rayleigh equation, some were found to require far more red than the normal, others required

25 Physiology of Vision.
26 'Zur Theorie der Farbenempfindungen,' Zsch. f. Sinnesphysiol., 51, 49–45.
27 Ibid.
an excess of green. Von Kries, in describing an extensive series of experiments, applied the name 'anomalous trichromates' to these cases, and this designation has gained universal currency. Guttman advocated the terms red-weak and green-weak, and distinguished seven characteristics which they manifest, the chief of which are high thresholds, heightened colour contrast and quick fatigue to colour stimuli.

It is customary to divide these anomalous trichromates into two groups corresponding to the two groups of dichromates, deuteranomalous trichromes or partial deuteranopes in which the sensitivity to green is below normal, and protanomalous trichromes or partial protanopes in which the sensitivity to red is below normal. The green anomalous seem to be more numerous than the red anomalous, the ratio being quoted as 5 to 1.

These cases, it may be, form the connecting-link between normal colour vision on the one hand, and colour defect on the other, and if a sufficient number of cases could be tested ranging from normality to complete red-green deficiency, a continuous series might be obtained. Below is a graph showing the results of testing 200 individuals, 100 women and 100 men with the Rayleigh equation, with rotating discs.

The results are expressed as logarithms of the ratio of red to green. For the 100 women tested, all the cases fall within the limits of the normal curve. In this respect, the results agree with those of Houston who tested with spectral lights, and who found of 105 women students, no scattered cases outside the normal curve.

The curve, in the case of the 100 men tested, presents different features. It is difficult to know where the normal curve ends and abnormality begins. The cases lying at the limits of the normal curve may be the extreme variants, or may be just outside it. Out of 423 men students tested, Houston found 15 outside the normal curve exclusive of colour blinds.

Edtridge-Green seems to apply the term anomalous trichromate to the extreme variants within the normal curve. Among 100 women, he found 14 who were anomalous, which means that he is describing cases as anomalous which lie within the normal curve. Other investigators apply the term only to the scattered cases outside the normal curve. It may be legitimate to use the term either way, but the definition of anomalous trichromasy will vary according to the usage of the term. If the anomalous trichromates lie outside the normal curve, then the difference between them and the normal may be qualitative, whereas if the anomalous trichromates lie within the normal curve, the difference may be only quantitative. It may be, as I have suggested elsewhere, that as results accumulate, the normal curve will spread out to reach these isolated cases, and the gaps between will fill up. Köllner, for example, reports transition cases between anomalous trichromates and dichromates, although none between anomalous trichromates and normal.

28 Article by Collins: British J. Psychology, 1929, 14, 387-393.
30 Ibid., 86B, 164.
31 Loc. cit.
32 Arch. f. Augenheilkunde, LXXVIII.
Hess 33 makes the interesting suggestion that many anomalous cases have been wrongly classed as colour weak because they do not accept the normal equation, when all that this proves is colour inequality, which may result from supernormal sensitivity to one colour. This is the objection Hess urges in connection with the use of the anomaloscope, namely that it detects those who are supersensitive to either red or green, or whose sensitivity to both red and green is reduced.

The normal curve evidently permits of fairly wide deviations. 'S' marked on the curve above is an anomalous trichromate because the excess of green required by him in determining the Rayleigh equation was very marked. Even when starting from the red end, he went right through equality to the green side, requiring considerably more green than normal. Nevertheless, he comes into the normal curve quite easily. It is curious to note that this subject had apparently a very low threshold for green, 10·5 as measured on the scale attached to the Drever-Hilger Hue-Discrimination Spectrometer. The average threshold for 30 subjects for green (5350 Å) using the method of serial groups for ten trials, worked out at 17·9 on the scale, the range of the readings for the subjects being from 5·4 to 30·8. His threshold for red (6700 Å), on the other hand, was higher than the average 25·6, as compared with 19·2, the range of the same subjects being from 7·0 to 29·0.

In the article already referred to by Pitt, the question is asked if anomalous trichromates form an intermediate stage between normal trichromates and dichromates. The writer quotes the well-known fact that the equation obtained by the normal does not hold for the anomalous trichromate and indicates that this may be a deciding factor for the negative. But he further argues, in terms of the Young-Helmholtz theory, that 'if the green curve moved over to the red until they coincided, the green curve would in effect have disappeared, and the dichromatic mixture curves would then become a reduced form of trichromatism, although in the intermediate stages the system would be a different rather than a reduced form.'

It is a moot point as to whether these anomalous trichromates form 'dangerous colour blinds.' The general finding seems to be in favour of the affirmative. Some writers, for example, Troland, actually include them in classifications of types of colour blindness. Oblath 34 points out that they can only recognise colours when they are saturated and of intense luminosity. 'It is evident that these peculiarities render these subjects less fitted for certain services.' In a report on Colour Vision Requirements in the Royal Navy, 35 it is stated that 'the mildly anomalous trichromate can be considered a safe look-out. On the other hand, the unfit anomalous trichromate is, in many ways a greater source of danger than the dichromate.' The incidence of this anomaly is estimated, in the same report, as 6 per cent., which is stated to be a very conservative

estimate. Both reports emphasise very strongly the fact that the anomalous trichromate behaves as if colour blind when conditions are unfavourable, such as when mist, fog or smoke are present, and this is all the more disastrous because the individual is rarely aware that he suffers from any colour defect. The heightened contrast and the quick fatigue, characteristic of such anomaly, may well make the judgment of colour and the discrimination of colour highly erroneous. The testing and discovering of these cases of anomalous trichromatic vision is not easy, and necessitates very careful procedure, and generally not the application of one test, but of a battery of tests.

The testing of colour blindness, indeed, in all its forms, presents a problem of great practical importance, involving the adoption of a definite technique.

As is well known, the adult colour blind avails himself of all kinds of secondary aids to enable him to discriminate colour. Identifying marks on the surface such as differences in texture or slight defects in material, or some minute details overlooked and undetected by the normal observer are readily made use of, so that it is possible for a colour blind who is aware of his abnormality to hide his defect in everyday life if he wishes to, and he can very often do so with surprising skill. In some cases, some sense, other than vision, may be utilised to help in discrimination. One individual examined by the writer—a case of shortened spectrum, in which one typical confusion is red with black—experienced difficulty with inks of these two colours. In marking a school register, he was constantly confusing the two colours, putting red ink where black should be, and vice versa. The discovery that he could distinguish them by smell solved his difficulties.

This obscuring of colour defect came to light recently in the writer’s experience in a rather curious way. In copying pictures from originals—given the outline of the picture and a box of paints with the names of the colours removed—the characteristic confusions generally appeared. One individual, however, often obtained matches of colour which were very similar to the original, and if only the final product were considered, his colour vision would be thought to approximate very closely to normal. To watch him at work was very illuminating, and one soon learned that many of his excellent reproductions were based on deduction. He knew foliage was green, for example; he also knew that blue and yellow mixed together produced green. His procedure was ‘to take what you think to be blue, and what you think to be yellow, and you should get what is called green!’ The green paint in the box, the exact match of the green in the picture, was not used at all.

An unusual case reported by Gildemeister and Dieter,36 is that of an engineer who was classed as a typical protanomal trichromate as the result of an anomaloscope test, but who some time later passed the test. As a trick was suspected, the anomaloscope was turned upside down, and the knobs adjusted so that they had to be moved in the opposite direction but still he was successful. It was surmised by the authors that he had

36 Arch. f. Ophth., 1922, 107, 26–29.
learned to accept an equation as correct which looked wrong to him. One of the investigators, himself a deuteranomalous trichromate, to put this possibility to the test, practised daily, and learned quite soon to recognise the normal equation, although it looked quite wrong to him.

These examples suffice to show some of the difficulties encountered in the detection of colour anomaly. Tests must be so devised that the person tested cannot avail himself of any secondary aids, but has to rely solely on his own colour sensations.

The spectrometer is undoubtedly the most fundamental test of colour vision, but it is seldom available for practical purposes, and the majority of tests, apart from those in scientific laboratories, are carried out either with some kind of lantern test or some kind of pigment test. There are various types of lantern tests available. The Edridge-Green Colour Perception lantern is the only one which has been used by the writer, and its advantages have been referred to elsewhere. A newer model is the Board of Trade Lantern Test, recommended with modifications by the committee set up to consider Colour Vision Requirements in the Royal Navy. In using this the eyes have to be dark-adapted for 15 minutes. The Giles-Archer Perception Unit is also a new and simple model, and it, too, requires the eyes to be dark-adapted. These lantern tests enumerated, and many others, have the advantage that coloured lights are used instead of pigments, which brings conditions of testing nearer to everyday conditions in the services, the railroad, navigation and aviation.

Certain pigment tests have also been extensively used, and it is these I should like to discuss in some detail. In some of these tests, it is puzzling to find mistakes made sometimes by individuals with normal colour vision which should only be made by colour blinds. The printing of the tests may be partially to blame, but it must be recalled that decisions are constantly being made on the results from these tests, and therefore it is essential to recognise which responses are diagnostic and which can be ignored. In order to reach a valid basis for diagnosis, I have given a battery of tests under constant conditions of distance and illumination to an unselected group of about 340 candidates applying to be accepted as apprentice printers, exclusive of colour blinds. Their responses, therefore, to the tests may be compared with the responses of a group of colour blinds tested under the same conditions. This normal group acts as a control group against which the results for each test used can be evaluated at its proper worth.

Owing to exigencies of space and time it will not be possible, nor desirable, in this address to discuss the details of the results obtained with all the tests which have been used. I have, therefore, decided to indicate the type of investigation under progress by giving the results from two of the tests only. The two tests selected are the Ishihara Tests for Colour Blindness and the Mosaic Plates devised by Schaaff.


The Ishihara test is composed of a number of pseudo-isochromatic plates in which coloured numerals appear on coloured backgrounds.

Collins: Colour Blindness.
The test makes use of the fact that blue and violet and yellow appear much brighter to the red-green colour blind than the colours red and green. Pitt questions this contention of Ishihara and asserts that 'blue is not bright compared with red and green: from the hue discrimination curves, however, it can be seen that blue is a colour having a noticeably different hue from red and green, and it is for this reason that blue is distinguishable for dichromates.' In some of the plates only part of a numeral appears to a person who is colour blind, this being dependent on the colours used. For example, an 8 may be the numeral read by one with normal colour vision, but only part of it may be seen by the colour blind, and he reads it as 3. Or a totally different numeral may be seen by the colour blind from the arrangements of the spots before him, and instead of seeing a 5 as the majority would do, he sees a 2 standing out distinctly from the background. Further, in some plates, the position is reversed as it were, and although the person with normal colour vision sees nothing but a blur of colour, the colour blind sees a numeral quite clearly. If one with normal colour vision looks at these plates through a blue glass, the 'hidden' numbers become visible.

The results from this test given to 42 colour blinds appear in Table I. The figures 12 are seen by all, normal and colour blind alike. The 8 appears as a 3 to the colour blind, the 6 as a 5, the 5 as a 2, and the 74 as 21. The next four plates, containing the figures 2, 6, 5, 7, are generally not visible to the colour blind, this depending on the degree of the defect. The two next plates contain figures which are hidden to the normal eye but are seen by the colour blind, a 5 and a 2 respectively. The two last plates are intended to diagnose the defect as one of deuteranopia or of protanopia. The deuteranopes read the 2 but fail to read the 6, the protanopes read the 6, but fail to read the 2. Similarly with Plate XIII. These plates seem to be diagnostic as will be seen from the table.

The individuals forming the control group who were tested were found to vary markedly in their colour discrimination. It seemed advisable to divide them into two groups termed respectively N (normal) and N — (showing greater deviation from the normal). The classification is of necessity an arbitrary one because it is difficult to know where to draw the dividing line; in fact, the line of demarcation between colour blinds and non-colour blinds may itself vary according to the purpose in hand. In the report of the Colour Vision Requirements in the Royal Navy, already referred to, it is stated of a certain test that if used alone it causes extravagant rejection of candidates who may be fit even for the Seaman Branch. This merely indicates that the standard for rejection can be changed in accordance with the post to be filled. It is interesting to note that three grades, so far as colour discrimination is concerned, are suggested in this report.

The colour blinds in the above table have been classified thus because of their responses not to any single test, but to at least six tests, and in some cases a spectrometric examination was also made. Similarly, in the N and N — groups, their allocation to these classes is based on the results obtained from the same battery of tests.

Collins: Colour Blindness, p. 44.
Table I.

Ishihara Test.

Results of Testing 42 Colour blinds.

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</tbody>
</table>
Table II.

Ishihara Test.

Frequency in percentages of normal and colour-blind responses for N, N—, and colour-blind groups.

<table>
<thead>
<tr>
<th>Plates</th>
<th>As read by normal</th>
<th>As read by C. B.</th>
<th>Normal N</th>
<th>C. B.</th>
<th>N— N</th>
<th>C. B.</th>
<th>Colour Blind N</th>
<th>C. B.</th>
</tr>
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<td>0</td>
<td>100</td>
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<td>55</td>
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<td>5</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>0</td>
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<td>4</td>
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<td>2</td>
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<td>74</td>
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<tr>
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<td>74</td>
<td>21</td>
<td>56</td>
<td>29</td>
<td>31</td>
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<td>81</td>
<td></td>
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<tr>
<td>6</td>
<td>2</td>
<td>—</td>
<td>99.0</td>
<td>83</td>
<td>1</td>
<td>0</td>
<td>100</td>
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<tr>
<td>7</td>
<td>6</td>
<td>—</td>
<td>100.0</td>
<td>96</td>
<td>4</td>
<td>5</td>
<td>95</td>
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<td>100.0</td>
<td>98</td>
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<td>5</td>
<td>95</td>
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<td>100.0</td>
<td>100</td>
<td>0</td>
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<td>98</td>
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<tr>
<td>10</td>
<td>—</td>
<td>5</td>
<td>91.4</td>
<td>89</td>
<td>6</td>
<td>4</td>
<td>95</td>
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<tr>
<td>11</td>
<td>—</td>
<td>2</td>
<td>72.27</td>
<td>48.48</td>
<td>0</td>
<td>100</td>
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<tr>
<td>12</td>
<td>26</td>
<td>or 6.5</td>
<td>99.0</td>
<td>90</td>
<td>1</td>
<td>5</td>
<td>59.1</td>
<td>10.1</td>
</tr>
<tr>
<td>13</td>
<td>42</td>
<td>or 2</td>
<td>100.0</td>
<td>100</td>
<td>0</td>
<td>10</td>
<td>55.1</td>
<td>26.2</td>
</tr>
</tbody>
</table>

The frequency of responses other than normal and colour blind has been omitted.


Table II shows the results from the Ishihara test when given to these three groups. The percentage frequency of the responses in each group has been calculated with regard to normal responses and colour-blind responses. The table is read thus: in plate V, 56 per cent. of group N read the figures correctly as the normal do, that is, read them as 74, whereas 11 per cent. of group N read the figures as the colour blinds do, that is, read them as 21. The frequency of responses other than normal and colour-blind has been omitted. In the N— group, 29 per cent. gave the normal response, 31 per cent. the colour-blind response. In the colour-blind group, 0 per cent. gave the normal response, 81 per cent. gave the colour-blind response.

Plates II and III are never wrongly read by either the N or N— group, but Plate III seems the better diagnostic test of colour blindness, as 71 per cent. of the colour blinds failed on it, and only 21 per cent. passed. Plate IV is equally good, although 5 per cent. of the N group and 4 per cent. of the N— group gave the typical colour-blind responses. Plate V which is read as 74 by the normal and as 21 by the colour blind is said by
Miles (39) to be 'certainly the most sensitive indicator of colour weakness that we possess,' and in the summary at the conclusion of the article, he suggests that in testing men for mercantile establishments, only Plate V need be used at the original interview. It is also regarded in the Report on Colour Vision Requirements in the Royal Navy as one of the most searching plates. It is true that 81 per cent. of the colour blind read the figures as 21, and the others in different erroneous ways, but if we look at the results from the N and the N— groups, we must modify our opinion. Only 56 per cent. of the N group passed, whereas 11 per cent. failed, that is, read the 74 as 21. The remainder read the 7 as a 2 or as a 9 or as a 1, so that the figures read as 24 (7 per cent.), or 94 (2 per cent.), or 14 (1 per cent.) or the 4 was read as a 1, and the numbers read as 71 (20 per cent.), or 91 (2 per cent.) or 11 (1 per cent.). In the N— group, the percentage of those passing is even smaller, 29 per cent., and the failures 31 per cent. The other variations also occurred. It may be, of course, that this plate offers a very delicate test of colour weakness, and therefore is very effective in picking out colour defect of varying degree. But sometimes it was the only error the individual made not only in this test, but in a group of tests.

The next four plates seem to be very significant. The normal group shows a perfect pass in all four, and the colour blinds almost a complete failure.

The next two plates containing the hidden numbers differ very much as regards efficacy for detection. The hidden 5 is certainly not visible to the normal eye, and the fact that 4 per cent. with normal colour vision saw it easily is a curious result. These 4 per cent. have perfect colour vision on all the tests, and one would be almost inclined to rate them as N+. Whether the supersensitive see the 5 or not requires further investigation. The 2, on the other hand, is not satisfactory. It could be seen fairly easily by all groups as will be evident from the percentages quoted. Twenty-seven per cent. of the N group and 48 per cent. of the N— group were able to read it.

The last two plates are very satisfactory.

The Ishihara test is a very reliable test of colour blindness and did not allow any of the colour blinds to pass. It also seems to detect colour weakness in a highly efficient manner.40

An attempt was made to investigate these plates with different-coloured filters to discover if possible the regions of the spectrum the light from which caused the figures invisible to certain varieties of colour blindness to become invisible to the normal eye, and the figures read by colour blinds to become visible to the normal eye.41

In order to obtain illumination from different regions of the spectrum, Ilford and Wratten filters were used. The light was that of an arc lamp

40 Dr. Rabkin, Kharkov, has forwarded to me a copy of a test he has just produced, Polychromatic Plates for Colour Sense Examination. It contains features similar to those of the Ishihara, though sometimes circles and triangles are substituted for numbers. From a preliminary survey, it seems very serviceable.
41 I am indebted to Prof. Drever for this investigation with the filters.
in a projection lantern. By means of an erecting prism, the beam of light was thrown downwards on a table, after passing through the filter, and the tests were placed on the part of the table so illumined. No other light was admitted to the room.

The first stage in the investigation was to determine the region of the spectrum transmitted by each filter. This was done by the Drever-Hilger Hue-Discrimination Spectrometer, and the following results were obtained. The results from the Ilford filters only are given here:

Ilford Filters.

<table>
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<tr>
<th>Color</th>
<th>End of Spectrum to</th>
<th>Violet</th>
<th>Blue</th>
<th>Blue-green</th>
<th>Green</th>
<th>Yellow-green</th>
<th>Yellow</th>
<th>Orange</th>
<th>Red</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>480μμ</td>
<td>450μμ</td>
<td>475μμ</td>
<td>500μμ</td>
<td>539μμ</td>
<td>555μμ</td>
<td>575μμ</td>
<td>620μμ</td>
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</table>

The following table (Table III) shows the results for the Ishihara test with the Ilford filters. The Wratten filters gave much the same results.

Table III.

<table>
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<th>Plate</th>
<th>Read by Normal</th>
<th>Read by C. B.</th>
<th>V.</th>
<th>B.</th>
<th>BG.</th>
<th>G.</th>
<th>YG.</th>
<th>Y.</th>
<th>O.</th>
<th>R.</th>
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</table>
It will be noted that with the violet and blue filters, the figures invisible and the figures read are precisely as we find them in typical colour blindness, except in Plate III where the figure 5 ought to be, and is usually read, and in the case of the blue filter, Plate XII, where the figure 2 or 6 ought to be read. With the blue-green filter, Plates VI, VII, IX, X, XI, give the typical colour-blind results also. Yellow, orange and red filters give the same result as in ordinary daylight. The results with the yellow-green filter are specially noteworthy. Plates IV, VI, VII, VIII, IX, can be read, but only with difficulty, when this filter is used. The results with Plates XII and XIII are also interesting, the plates inserted to distinguish between deuteranopia and protanopia. In Plate XII, the normal read 26, the deuteranopes 2, and the protanopes 6. On Plate XIII, the normal read 42, the deuteranopes 4 and the protanopes 2. With the violet filter, 6 was read on Plate XII, and 2 on Plate XIII. With the blue and blue-green, green and yellow-green filters, nothing could be read on Plate XII. On Plate XIII, on the other hand, 2 was read with the violet and blue filters, and 4 with the blue-green, green and yellow-green filters. To the normal eye in white light there is no apparent difference as respects colour between the pages.

2. Tableaux-Mosaïque pour la Recherche du Daltonisme.

Schaaff's Mosaic Plates consist of ten cards, on each of which appear on coloured backgrounds two coloured circles, one smaller than the other. Each circle is incomplete, and the test consists in asking the subject to point out the gap or break in each circle. The cards are square and can be turned round to any angle when placed on the table, so that the circles do not always appear in the same position.

This test failed the group of colour blinds quite definitely when the results are considered over the whole test (see Table IV). The number of the gaps seen, however, is not constant for each individual, but ranges from 3 to 16. The test does not seem to differentiate between deuteranopes and protanopes. Plates II, VIII, and X should be seen better by protanopes, Plates VII and IX by deuteranopes. This does not hold consistently. Only two colour blinds saw the gaps in Plate II, and they are protanopes, but the other protanopes failed to do so. Some of them described the card as being composed of nothing but gaps, 'gaps all over,' and they did not know which one to point to. As a matter of fact, the circles on this card offer difficulty to people with quite good normal vision.

Plate VI is an interesting one. The instructions run that those who fail in Plate VI should not be admitted as engine-drivers unless there is a shortage of applicants. All the colour blinds failed in this card except one who half passed, that is, who saw the gap in one of the circles but not in the other. Table V shows the results of the tests given to the control group as well as to the colour blinds.

Plate I is seen by all. Plate II is clearly quite difficult, only 60 per cent. of the N group managed to point out the gaps in the circles, and only 37 per cent. of the N — group. In the colour-blind group, on the contrary, only 7 per cent. passed, and there is a failure of 78 per cent. Plate VI failed 6 per cent. of the N group, 17 per cent. of the N — group, and 98
Table IV.  
Schaaff's Mosaic Plates.  
Results of testing 40 colour blinds.

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V = pass: X = saw the circle but did not locate the gap: — = could not see the circle.
Table V.

_Schaaff’s Mosaic Plates._

Frequency in percentages of normal and colour-blind responses for N, N — and colour-blind groups.

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<th>W.</th>
<th>N — C.</th>
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C = correct both circles: ½C = one circle correct, one wrong:

W = wrong, both circles.

Per cent. of the colour-blind group. These two plates alone, number II and number VI, are severe tests of colour perception.

Of the test as a whole, 43 per cent. of the N group made a perfect score, that is, pointed out the gap in each circle correctly. In the N — group, only 24 per cent. passed, and in the colour-blind group no individual made a perfect score. Sometimes, in all groups, the shape of the circles could be recognised but the gaps could not be located. When the rings are recognised, but not the gaps in certain tables, only slight weakening of the colour sense is indicated, but when the rings are not recognised, the defect is of a more serious nature. In the instructions accompanying the mosaics, the following words appear: ‘Quiconque ne discerne pas les anneaux et les brisures dans les dix tableaux, n’a pas le sens chromatique normal.’

The final estimate of this test is that it can be recommended as a fairly satisfactory test of colour blindness.

A supplementary test, devised by Schaff and Blum, consists of 30 cards on which are diamond-shaped spots. Some of the cards contain one colour only, but in varying shades, green of more than one shade, or red, or grey. Some of the cards have more than one colour on them. The subject is asked to sort the 30 cards into piles—a pile of cards in which all the spots are red, a second pile in which all the spots are green, and
a third pile in which all the spots are grey. This part of the test is supplementary to Part I, and undoubtedly does reveal any colour defect. The colour blind presented the same heterogeneous collection of colours as they normally do, the colour weak placed certain of the greys among the greens, and so on. In this part of the test difficulty was sometimes experienced by the normal colour group as to the correct pile into which a card should go—if a blue-green, for example, should be placed among the greens or be in the left-over pile, if a reddish-brown should go with the reds or be omitted. A further part of this test is to give one card which has green and red spots on it of three different shades to the subject and ask him to select out two cards in the pack which match these exactly. This means selecting one card with red spots of the same shades, and one card with green spots of the same shades. This proved difficult both to normal and colour blind individuals. Some of the colour-blind gave the task up as hopeless, only 2 out of those tested being successful. With the N — group, 33 per cent. were successful, and with the N group 60 per cent. were successful. This part of the test, the sorting and the matching, while of interest to an examiner, has not the same practical value as Part I of the test, in which the break in the circle has to be recognised. It could be dispensed with altogether, except in cases of doubt, where confirmation of or further information about a defect was required.

The results from these two tests may be sufficient to give some idea of the type of investigation which has been carried out. A similar analysis of the results obtained with other pigment tests—the Stilling, the Nagel, the Podesta, the Edridge-Green, etc., leads to similar conclusions, namely, differences in the value of individual tests, inconsistencies in the findings arrived at with any single series, and so on. As regards the Stilling test, the complete investigation covers only the first three plates of the seventeenth edition. These are found to give very satisfactory results both in detecting colour blindness and in differentiating between the two types. It is unfortunate that the formation of the figures used in the plates is not clearer, because this gives rise to a number of trivial mistakes which may be misleading to an inexperienced examiner. Such errors are to mistake a 3 for an 8, or vice versa, or to confuse the figure 2 with 7.

In the latest edition of the Stilling (the nineteenth edition) the same figures are used, so that the same confusion appears. There are, however, several new features, including the insertion of hidden numbers, which are only visible to the colour blind. The results from this series are not so clear-cut as in the earlier editions, and there is no reason to suppose that it can yield more reliable or more consistent results than the others. It is interesting to note, however, that the examiner is encouraged to ask subjects to trace the shape of the figures with a wooden rod, to point out dots of a similar colour to the one indicated, both useful devices in ordinary testing, as also in cases of dissimulation or where it is suspected that the subject has been coached in the test. Also, it is suggested that if in doubt, the subject can be asked to read some of the plates through coloured filters. This is a device which could well be followed with
almost any of the pigment tests with satisfactory results, as the subject
can have no idea beforehand what he should see.

The Nagel card test came out very badly in the investigation. It is
apparently less reliable than even the simple Collins-Drever Group test,
devised as a first aid in revealing cases of colour blindness among school
children. It allowed a number of colour blinds to pass with a perfect
score, and some others only made a very slight omission, not serious
enough to place them in the category of colour blind.

The Edridge-Green card test is very difficult for those with normal
colour vision, as well as for the colour blind. It certainly failed all the
colour blind, but it also failed a great many others. Of the control group,
only 23 per cent. of the subjects passed, the others being rejects, a result
sufficient to show its stringent nature. The test is based on Edridge-
Green's theory, and the cards are intended to indicate if the individual
tested is to be classified as a dichromic, a trichromic, a tetrachromic and
so on. The results are accordingly difficult to interpret.

Although tests of colour blindness of a severe type are essential in
certain vocations, they do not seem to be so necessary for all vocations,
and some simpler tests may serve the purpose equally well. It would
be very rash to suggest any one test as being a perfect test of colour
blindness, and most examiners prefer to compare the findings from at
least two tests before venturing a diagnosis. A combination of the
Ishihara, the first three tables of the Stilling, and the Schaaff Mosaic test
should give a fairly satisfactory diagnosis of colour blindness. These
tests should be diagnostic enough to yield reliable results for vocations
in which colour discrimination is desirable, other than those in which
coloured signals are used. In vocations, however, in which coloured
signals require to be discriminated as on the railroad, in certain branches
of the Navy, in aviation and to a lesser degree in motoring, some form of
lantern test should be given in addition. As well as bringing conditions
nearer to conditions in these vocations in which lights have to be dis-
tinguished and not pigments, a lantern test also involves colour naming,
which may yield useful supplementary evidence.

There is a good deal of doubt, however, whether we ought to speak of
reliability and consistency at all in connection with the results of this
analysis. It may be that the discrepancies disclosed are due to the great
variety of those deviations from normal colour vision which are so marked
as to justify their being regarded from a practical point of view, as cases
of colour blindness. This interpretation of the facts is to some extent
confirmed by the results of filter analysis. Plates which all profess to
diagnose deuteranopia for example, show very differently under filter
analysis, and similarly evoke different responses from different deuter-
anopes. The inference would appear to be that we are dealing not with
linear variations in degree but with multidimensional variations. A wide
new field for investigation is thus disclosed, the working of which may
yield valuable results for the whole theory of colour vision.
SECTION K.—BOTANY.

THE MODERN STUDY OF PLANTS IN RELATION TO EDUCATION

ADDRESS BY
PROF. E. J. SALISBURY, D.Sc., F.R.S.,
PRESIDENT OF THE SECTION.

In choosing as the subject of my Address a more general rather than a special theme I have not been unmindful of the fact that this is one of the few occasions on which it is permitted to dwell on the wider application of one’s subject untrammelled by the presence of a purely specialist audience and unchallenged by the imminence of debate.

I hope I have not been tempted unwarrantably to voice my passing thoughts on the broader considerations of the educational value and contacts of our subject by the happy consideration that these words of mine will find a peaceful resting place between the covers of an Annual Report whence they can only be exhumed by deliberate intent.

When we cast our minds back on the general attitude adopted towards our subject in the latter part of the eighteenth century we cannot but be struck by the almost apologetic phraseology of its votaries and the curious grounds upon which they rationalised its pursuit. Rousseau, for example, described Botany as a study of pure curiosity that has no other real use than that which a thinking, sensible being may deduce from the observation of nature and the wonders of the universe. I venture to think that many otherwise educated people to-day would express similar sentiments, though in more modern and probably less complimentary language.

There are many who regard the botanist as one whose main preoccupation is to recognise plants and to name them, capacities which, I am sure most of my professional colleagues will agree, are perhaps the least widespread to-day of those which the compleat botanist should possess. Indeed, the layman is so often disappointed in the professional botanist’s capacity to label plants that he rates our occupation even lower than before.

The teaching of our subject has been in no small degree to blame for the widespread misconceptions as to its aims and content. For long regarded as a harmless and elegant occupation for the female sex, Botany only survived as a study of practical utility because of the continued necessity for medical practitioners to acquire some knowledge of Materia Medica. How perfunctory was much of this teaching is indicated in that charming book Leaves from the Life of a Country Doctor, where the late C. B. Gunn describes how as a medical student in 1878 ‘the botany class gave me a “scunner” at the subject which has lasted ever since.’
fessor Balfour,' he continues, 'a very kindly man, was well named "Woody fibre," as his teaching of what might have been a most interesting subject was of a singularly wooden and fibrous nature.' It is perhaps only fair to add that the lectures of his son are reputed to have been as interesting as those of his father were apparently dull.

The old technological significance for Medicine has long since gone, but a newer and vastly more important significance remains, both cultural and vocational, which has rarely been stated, let alone stressed. Despite the vastly enlarged content of botanical knowledge since those days the general conception of Botany has remained much what it was then, and the fact that we so often have to deplore previous training in the subject of students who come up to the Universities is, I think, sufficient proof that the woody fibres of mere description still predominate over the functional presentation of the living plant.

What I would particularly wish to urge is that the high value of Botany as an educational subject and indeed its absolute necessity in any system of real cultural development is an aspect which we botanists have failed to present and emphasise, perhaps too often even to realise ourselves.

The protagonists of compulsory Greek and Latin of the last century valued very highly, and rightly so, the cultural content which a study of the humanities could provide. It is easy for us to be wise after the event, but now that the dust of that controversy has cleared away we can see that failure to apprehend that there are other approaches to the same mental salvation led to an unfortunate insistence upon the means rather than upon the end.

But whilst scientists justly claim that cultural value is the monopoly of no one subject and that those brought up in the classical tradition may be as much philistines as any scientist it is undoubtedly true that the immense cultural potentialities of scientific thought have too often been neglected for the sake of mere erudition.

There is a general tendency for university teaching to become more and more vocational as the specialised demands of occupations become increasingly exacting.

Thus not only do technological aspects grow more obtrusive, especially in the final courses of certain subjects, but there is a trend, in the direction of this change, making its influence felt, further and further back in the student's training, so that we find, for example, certain sections of the medical profession demanding that the preliminary education should have a more direct bearing on the future occupation of the student, despite the fact that this can only be accomplished at the expense of their general education and culture. With the long course of training which most professions to-day require and the financial strain that this often involves upon parents, one cannot but sympathise in the wish to provide some relief, but if this is to be accomplished without detriment to the ultimate standing of the professions themselves it can only be by an increased concentration on the more general aspects of culture in the schools. So far as biology is concerned there is a widespread recognition for the need of greater attention to training in observation in the schools allied to what may be termed the scientific study of Natural History. Too much attention in this as in other subjects is paid to the acquisition of
mere information, especially if recent, too little to the principles which are involved. This is not intended as a stricture upon the teachers, since, with our present system, earlier and earlier in the students’ career they are striving to achieve a dual objective, the training which should be their chief concern and their preparation for University examinations at a stage in mental development which cannot adequately appreciate the educational content of the curricula. Thus the student who has taken the Intermediate Examination from school is often handicapped in comparison with those who would appear to be starting their University career in a less advanced stage.

Just as the increased demand for material things facilitated the replacement of the products of the craftsman by mass production of machine-made articles, so too the rapid increase of population following the industrial revolution inevitably led to something analogous to mass production in the education of children and the training of teachers.

Many there are who blame the examination system, which, however, with all its faults, if rightly used, is in reality a fairly efficient sieve for separation where large numbers are involved. But the examination machine is often expected to effect a grading of the human material with which it deals that can only be attained by more individual methods. As a consequence undue importance is attached to examination results and a wrong emphasis is often laid on their significance. This leads to a premium being placed on mere erudition and so subjects are liable to be taught not as living realities but, in the forceful phraseology used by Winston Churchill in one of his novels, ‘Knowledge is presented as a corpse which bit by bit we painfully dissect.’

Furthermore our educational methods are, I fear, too often divided in their allegiance; on the one hand we aim at the provision of a liberal culture which will make for the greatest happiness of the individual, considered in terms of mental contentment and an abiding resource in later life; whilst on the other hand we aim at the equipment of the student for the earning of his daily bread to ensure bodily comfort. We are not sufficiently trustful that the provision of the former is, to employ the expressive northern phraseology, the ‘gainest way’ to the latter end, and so we adopt a sort of mental squint—which permits neither of the clear vision of the full beauty of integrated knowledge nor even of keeping our eyes on the main chance. It is no more possible in education than in ethics to serve both God and Mammon. It is not merely good education but the apotheosis of worldly wisdom to seek first the cultural background and believe that the vocational proficiency will be added unto you.

The Universities cannot be held blameless for the lack of appreciation by the general public of the implications of our subject. May I, in this connection, quote a passage from an American report on University Education which loses none of its cogency on this side of the Atlantic: ‘Appointing authorities too often place undue stress on specialisation, instead of placing adequate emphasis on scholarly background, versatility of intellectual interest and general culture.’

Whilst activity and distinction in research is a necessary qualification of the teacher, the capacity to impart knowledge to others is no less essential. Too often in the selection for University posts aptitude as a teacher, which should be a first consideration, is entirely subordinated
to distinction as an investigator. No one, it is true, can be an inspiring teacher who does not possess intellectual initiative and who is not engaged in a creative pursuit, but most of us have suffered at one time or another from the investigator 'whose thoughts are too full for words.'

Furthermore we must avoid the undue sacrifice of breadth for depth for other reasons.

The accumulation of data and the provision of information bears much the same relation to the advancement of knowledge as artificial fertilisers to crop production. Just as our fertilisers must be properly balanced, so too our information must be so correlated and concerted that ignorance in one department does not become the limiting factor in our utilisation of extensive data in others. In these days of extreme and increasing specialisation such correlation of effort is becoming more and more important, and it is to the Universities, old and young alike, that we must look for the maintenance of that contact and synthesis which is essential to real progress. Because the research worker to-day delves more and more deeply into the mysteries of nature than ever in the past, the field he explores is correspondingly more restricted, and hence it is more necessary than ever before that those who devote themselves to science should have a wide background of culture. In particular I should like to urge that the time has come when the curriculum required of those proceeding to a University degree in Science should be reconsidered. It is, in the present state of knowledge, as much an anachronism that a student should be able to proceed to a degree in Chemistry having no knowledge of Biology as that he should proceed to a degree in Botany with a mere smattering of either Physics or Chemistry. Anyone who aspires to a degree in Science should in my opinion have an adequate appreciation of the principles of Physics, Chemistry, Mathematics, especially as regards statistical methods and probability theory, and lastly, but by no means least, one biological subject, preferably Botany, since relation to their physical environment and the laws of heredity are more easily studied in plants than in animals, and the animal kingdom is, after all, dependent upon the vegetable. Four obligatory subjects in the first year University course might and probably should involve the return to a five-subject Intermediate examination in Science, so that a fifth optional subject would permit of the desirable freedom of choice in respect to subjects pursued in the more advanced stages. But further, it may be stressed that some biological training is to-day an essential to any liberal culture and should be as much an obligatory part of a school curriculum as arithmetic.¹

Whatever views we may hold with regard to the respective merits of the vitalistic and mechanistic schools of thought in relation to organisation, the incontrovertible fact is that in the present state of knowledge we are quite unable to express and indeed cannot hold out any prospects of explaining, the phenomenon of life in terms of physics and chemistry alone. Such a view is quite independent of whether or not we speculate as to what the future may hold in store. At present therefore there are

¹ Such restrictions of choice to a single optional subject would more than compensate for any time-table difficulties that might result from the number of subjects being increased from four to five.
certain aspects of the universe such as heredity, development and the reaction of the organism to the environment which must be studied in other respects than merely the chemical and physical states with which they are associated, and hence biological knowledge is as fundamental to our understanding of the world around us as either physics or chemistry.

One great merit of botanical study from the standpoint of general education is that, if properly taught, it provides perhaps the best medium for training in accurate observation.

Observation consists essentially of two separate processes, namely, seeing the object or phenomenon and the apprehension of what is seen. The visual perception of the good and bad observer may be alike adequate, but it is in the degree of their apprehension that they differ. To train such powers it is essential to check the accuracy of appreciation either by means of verbal description or graphic representation. The graphic method is clearly more suited to the adolescent mind whose limited vocabulary and limited feeling and understanding of the nuances of meaning of words unduly restricts his verbal precision. Drawing, if regarded strictly as a statement of observed facts, offers the best means of such training, and botanical material, because of its well-defined organisation, is peculiarly suited for this purpose.

But, from the cultural standpoint, plant life and all that it implies may be regarded as the foundation of a vast extent of human activity and the basis of a large and essential part of every human environment. Because neither we nor the animals could persist without plant life it follows that much of the present distribution of these organisms over the face of the earth can only be understood in terms of the plant life either of the present or the past. Even man’s industrial activities have been largely localised and in part determined by the geographical distribution of vegetation whether it be that of the forests, of perhaps 280 million years ago, which gave origin to our coal deposits, or the vast extent of grasslands that have determined the location of pastoral communities.

It is no exaggeration to say that an adequate appreciation of geography, unless merely descriptive, is not possible without an adequate background of botanical equipment. Yet teachers of geography, let alone students, are too often ill-equipped in this prerequisite.

A realisation of the widespread demands made upon plant products would probably astonish many of those who, like Mr. Babitt, find in the mechanistic devices of the age their chief delight. Yet it has been recently estimated that a thousand Ford motor cars utilise in their manufacture the entire plant yield of over six hundred acres, and this quite apart from the indirect demands for grazing necessary to furnish the materials of animal origin. Despite the vast areas of the earth’s surface devoted to the growth of foodstuffs, of textile fibres, of timber, rubber, tea, tobacco and innumerable other plant products, the plant remains perhaps the least known and appreciated of all man’s servants by those who lay claim to any cognisance of their environment.

Even the town dweller can scarcely fail to recognise the indirect contacts of his everyday existence with the activities of agriculture, forestry and horticulture, and, if education is to be interpreted as a means of enabling the individual to have an intelligent appreciation of and
harmonious relations with his environment, then a knowledge of plant life is manifestly essential to that end. I should almost feel that an apology was necessary for expressing sentiments so trite were I not sure that whatever agreement there may be in theory, our educational curricula bear witness to the neglect of these principles in practice.

As a branch of knowledge we botanists have been fortunate in successful avoidance of the process of fission that other subjects have suffered but, in maintaining our integrity, we have by no means remained immune from cell division and, if one may push the simile further, the protoplasmic connections between cell and cell have in certain directions become very much attenuated. It is neither in the interests of our subject as a whole nor of its individual parts, still less does it contribute to its cultural value, that after a six months' abstinence from perusal of a particular branch one returns to find oneself out of touch, not with the principles involved but with the terminology in which those principles are couched. Even in the matter of plant names themselves we suffer from the antiquarian researches of those who, clinging to the letter of the law of priority, forgo the spirit of mutual understanding it was intended to serve. Whilst in every branch highly technical expression is sometimes warranted by the necessity for precision, it may easily become the cloak of mental laziness and is almost invariably the sign of either immaturity of conception or stagnation of ideas.

The increasing diversity of pursuits in a progressive science is only too liable to be accompanied by an increasing detachment of interests and divergence of expression. Specialisation, which should be accompanied by greater co-ordination, is only too frequently the begetter of disintegration rather than synthesis and the mutual interdependence of one branch on another is lost sight of.

One of the main purposes which the British Association should serve is to promote the co-operation between workers in different fields. But we only come together for a short week in each year, and so it is to the Universities that we must look mainly for the continuous fostering of a liberal outlook both on science as a whole and within the domains of each particular subject.

In its earlier phases Botany was naturally concerned largely with description, and in such branches as Taxonomy, Morphology, Anatomy, Cytology, Mycology, Palaeobotany and Plant Geography the descriptive aspect must necessarily play an important rôle just as in Ecology, Physiology, Bacteriology, and Genetics the experimental aspects should predominate. But in all, the cultural value can only be maintained if form and function are closely integrated. Each branch has its own contribution to make in this respect not only to the pure science but to its applied aspects in Agriculture, Horticulture, Pomology, Sylviculture and Plant Pathology. The mere enumeration of these branches, whether pure or applied, envisages the richness of the field we cultivate and the extensive contribution that Botany can make towards both the enrichment of the human mind and the well-being of the race. But the accumulation of data in these varied directions of enquiry will only fulfil its full purpose if the many threads are continually woven into the warp and woof of a single fabric.
The retention of plant physiology within the domain of Botany has saved us from the worst evils of the study of form unrelated to function. This has also been one of the chief factors which led to that synthetic approach to our subject which concerns the relation of the plant to its surroundings. The supreme value of ecology, however, lies not so much in the attention which it focusses upon the mutual relations of organisms or even upon their relation to the environment, but in the synthesis which ecology achieves, into a single picture, of so many aspects of Botany itself and so many branches of human knowledge. Its high educational and cultural potentiality is an outcome of the fact that it is the very antithesis of that common failing of the human mind to think of different subjects as isolated compartments of knowledge and not as different facets of one and the same jewel.

When we attempt to understand any plant community the necessary study of the physical environment leads us at once into realms of soil structure, into the physical problems connected with water retention and water movement involving colloid properties and surface action. So, too, the chemist and the meteorologist make their contributions to our concept of the habitat, whilst the bacteriologist, the mycologist, and the protozoologist all help us to envisage that teeming population of bacteria, fungi and protozoa in the soil which, by their proper balance, maintain a healthy circulation of chemical products and are a necessity for the maintenance of the supply of raw material for the higher plants and animals.

But, since the environment of the present is in some considerable degree the consequence of that of the immediate and sometimes of the remote past, the study of external conditions brings us into contact with the contributions of glaciologists and historians, whilst even the student of ‘place names’ may materially assist in the reconstruction of those past conditions that in part have determined the present state.

When we turn from the study of the habitat to that of the vegetation which it supports we are at once confronted with the question as to the extent to which the one is in equilibrium with the other.

The morphologist and the anatomist furnish the data upon which we base our judgment as to the degree to which the external form and internal structure have contributed to render the organisms suited to the environments that they frequent. In so far as there is adaptation, whether passive or active, in this respect, to that extent the community is in equilibrium with its surroundings and represents a climax, subject it is true to secular change but of a relatively stable character.

The contribution of the systematist is to distinguish between the more critical species and races which exhibit a localisation that less meticulous examination might readily ignore and which often have an ecological importance far greater than the Linneans of which they are the segregates. The experimental conclusions of the physiologist in the laboratory must be applied by the ecologist to the elucidation of problems in the field complicated and often profoundly modified by the continual operation of the competitive factor.

Finally, knowledge of the life histories of the constituent organisms, the reaction of the various phases of their development to the environment, their modes of reproduction, their establishment and extension, comprise
a mass of knowledge to which many astute observers have contributed and amongst whom the amateur holds an honoured place in our esteem. The clichés of the politician with regard to policies might be applied with far more than their usual significance to the ecologist, who might with some reason be described as ‘exploring every avenue’ and ‘leaving no stone unturned’ in his attempt to reveal the causal relations underlying the social organisation of plant life; but this all too brief résumé of the contents and contacts of a single branch of Botany has, I hope, sufficed to emphasise that the wide range of knowledge invoked by the ecological approach, though constituting its chief difficulty, is the very basis of its cultural value, since it weaves together into a comprehensive whole so many threads of knowledge spun by the specialists upon the wheels of research.

The value of such approach is also obvious in relation to everyday affairs. In any well-considered plan of land utilisation of catchment areas the ecological aspects are apt to be ignored. The land surface under its various guises may be likened to a sponge which absorbs the divers forms of precipitation and allows the water with more or less rapidity to find its way into the streams and rivers. Under ideal conditions the effectiveness of the sponge provided by forests may regulate the water drainage to such a degree that despite extreme fluctuations of rainfall the river levels exhibit no abnormal oscillation; but the effectiveness of the land surface for holding back the water varies according to whether it is under high forests, scrub, grassland, or arable. Each type of plant cover has its own absorptive factor and its own resistance to erosion. Furthermore, each vegetation type is not static but dynamic, and its rôle in this respect changes both with the seasons and with the passage of time. If therefore our land utilisation is to be properly conceived, due regard must be had to the proportions in which the various communities, whether natural or artificial, are present. If we are to avoid floods and droughts, we must preserve rural England for practical as well as æsthetic reasons. To all this ecologists can contribute valuable help, the more so that with the passage of years the surface of our roads has become better and less absorbent, our ditches are kept cleaner so that drainage to rivers has generally become more effective and rapid. Hence what sufficed to restrain extreme conditions a hundred years ago would not suffice to-day. Afforestation of the catchment area of the Thames and other rivers would, in the long run, be perhaps far more effective and less costly as a guarantee against future floods or droughts than grand scale engineering works, and whilst the former would produce ancillary assets of great value the latter would not.

Classical examples have been afforded in the past by areas in France where as a result of clear felling in the early part of the present century the water table rose over three feet. The detailed records from the state forests of Moudon showed that the average water table under both deciduous and coniferous forests was not only much lower than in the surrounding open country, but was subject to much less marked fluctuations. The recent occurrence of the disastrous floods in the Ohio and Mississippi valleys and the equally tragic droughts responsible for the American Dust Bowl, involving an area more than twice that of the entire British Islands, are too recent in our minds to need recapitulation. Such
events are, I think, too apt to be conveniently dismissed as ‘acts of God’ in the comfortable belief that the causes are beyond our responsibility or control. But like our own droughts and floods they are in no small degree capable of regulation by the proper utilisation of plant cover. It is perhaps nothing more than the truth to assert that the provision of wood for the smelting of iron on the Weald of Kent, or the maintenance of the fuel supply for the salt pans of Droitwich has, *inter alia*, its repercussions in our own water economy of to-day. It is now probably recognised by many that these extremes of water supply are in large measure the outcome of lack of vision in respect to the proper integration, both spatial and temporal, of our exploitation of the soil surface. To-day, however, we find that it is the engineer who has to be called in to mitigate results rather than the biologist to remedy the cause.

This is partly because the engineer’s remedies, though extremely costly, are usually more immediate in their results and certainly more spectacular, but largely, I think, because botanical knowledge on the applied side is inadequately organised to fulfil the important rôle it can and should play in co-operation with the engineer for the communal well-being.

Professor F. W. Oliver pointed out, in reference to the reclamation of foreshores, that the plastic plant can and does meet the constantly changing impact of the forces of nature in a way which the dead material of the engineer cannot hope to emulate, and at a far lower cost. But such biological control demands not only a comprehensive knowledge of the life histories of the species utilised but also an appreciation of the environmental factors dynamic as well as static that is summed up in the phrase ecological foresight. As an example of the type of investigations which are calculated to provide the necessary data one might cite the studies of Professor Weaver and his colleagues on the root systems of American prairie species and on the effectiveness of the plant cover in the prevention of erosion. Mr. F. N. Ratcliffe’s summary of the position on the arid pastoral regions of South Australia has shown that the erosion there is largely an outcome of overstocking with grazing animals, which took no cognisance of the normal climatic fluctuations, with the result that plant growth in dry seasons could not keep pace with the loss of protection from wind due to grazing.

Another matter to which I should like to refer in this connection is the much discussed question of the preservation of natural areas. The public generally needs guidance on these matters which the student of plant life should furnish. Owing to the widespread ignorance of biological knowledge the dynamic character of vegetation is by no means widely realised. There are indeed many educated people to-day who think that to preserve an area all you need to do is to leave it alone. The fact that your open downland, presented to the National Trust, may, if left unhindered, ultimately cease to be downland and become woodland with the loss perhaps of the very features for which the area was preserved, is for most a novel concept. The transition phase between grassland and woodland that we term open scrub is perhaps at once the richest in species of flowers and insects of all our natural plant communities and the most transient. To preserve such it is necessary to remove trees and shrubs just at the period when they would appear to be approaching
their prime. But an enlightened policy of such control of national reserves and all that this implies will only be possible if the rising generation has been inculcated into a biological mode of thought. So, too, the preservation of our insect and bird fauna and of our fungal flora demands a considered policy with respect to continuity in the supply of decaying and fallen timber, which as I am personally aware the guardians of some areas find to be a hard saying.

Mr. Ramsbottom, in his Presidential Address last year, admirably emphasised the practical importance of the study of mycology, the many ways in which fungi play an important part in industry and everyday life. The importance of algae in relation to our fisheries has been revealed by the investigations carried out in the Marine Biological Station at Plymouth, whilst the Fresh Water Station of Windermere is rapidly increasing our knowledge of the rôle of algae in relation both to fresh water fisheries and to water supply. The practical value of genetics and plant breeding in the production of better and more disease resistant strains is so obvious as to need no emphasis. Indeed it is probably true to say that no branch of botany could be cited that has not its important practical applications. Botany needs no defence in respect to the practical utility of its pursuit, although it is probably true to say that the majority of those who reap the benefits of its achievements are unmindful of their source. But it is, I feel, the contribution that botanical knowledge can make towards general culture and spiritual contentment that is its chief claim to rank high in our educational scheme.

For the future I venture to suggest that it is not so much the paucity of data that needs to be made good, as the failure of the botanist to take his proper place as a man of affairs. We have been too content in the past to pursue the pleasant paths of pure science, heedless of the implications of our results, with the outcome that our subject has not received the measure of moral and financial support that its value to the community would justify.

In no direction is research more needed that in a detailed knowledge of the autecology and biology of our commonly cultivated species, yet, as I have pointed out in The Living Garden, there are several respects in which our knowledge urgently needs augmenting. But until the number of posts, other than teaching posts, open to botanists is increased so that a research worker in this field has an assurance of a competence and reasonable prospects if he proves efficient, the number of first-class botanical investigators will remain few and many of the best brains who might be attracted to it will continue from sheer force of circumstance to adopt other and more lucrative professions.

A sympathetic understanding of botanical thought and progress is essential to a community which is to deal adequately with such national problems as agricultural policy, land utilisation, afforestation, drainage and water supply, the preservation of rural areas or the provision of national parks. Only on the foundation of a knowledge of plant life and its requirements can an educated public opinion be built up that will receive and give effect to well-considered legislative action. Moreover, it is perhaps truer of these pressing questions than of most that a sympathetic and informed public opinion is essential to the continued effective operation of any policy however well conceived and enlightened.
SECTION L.—EDUCATIONAL SCIENCE.

THE INFORMATIVE CONTENT OF EDUCATION

ADDRESS BY

H. G. WELLS, D.Litt.

PRESIDENT OF THE SECTION.

Section L of the British Association is of necessity one of the least specialised of all sections. Its interests spread far beyond professional limitations. It is a section where anyone who is so to speak a citizen at large may hope to play a part that is not altogether an impertinent intrusion. And it is in the character of a citizen at large that I have accepted the very great honour that you have offered me in making me the President of this Section. I have no other claim whatever upon your attention. Since the remote days when as a needy adventurer I taught as non-resident master in a private school, invigilated at London University examinations, raided the diploma examinations of the College of Preceptors for the money prizes offered, and, in the most commercial spirit, crammed candidates for the science examinations of the university, I have spent very few hours indeed in educational institutions. Most of those were spent in the capacity of an enquiring and keenly interested parent at Oundle School. I doubt if there is any member of this section who has not had five times as much teaching experience as I have, and who is not competent to instruct me upon all questions of method and educational organisation and machinery. So I will run no risks by embarking upon questions of that sort. But on the other hand, if I know very little of educational methods and machinery I have had a certain amount of special experience in what those methods produce and what that machine turns out. I have been keenly interested for a number of years, and particularly since the war, in public thought and public reactions, in what people know and think and what they are ready to believe. What they know and think and what they are ready to believe impresses me as remarkably poor stuff. A general ignorance—even in respectable quarters—of some of the most elementary realities of the political and social life of the world is, I believe, mainly accountable for much of the discomfort and menace of our times. The uninstructed public intelligence of our community is feeble and convulsive. It is still a herd intelligence. It tyrannises here and yields to tyranny there. What is called elementary education throughout the world does not in fact educate, because it does not properly inform. I realised this very acutely during the latter stages of the war and it has been plain in my mind ever since. It led to my taking an active part in
the production of various outlines and summaries of contemporary knowledge. Necessarily they had the defects and limitations of a private adventure but in making them I learnt a great deal about—what shall I say?—the contents of the minds our schools are turning out as taught.

And so now I am proposing to concentrate the attention of this Section for this meeting on the question of what is taught as fact, that is to say upon the informative side of educational work. For this year I suggest we give the questions of drill, skills, art, music, the teaching of languages, mathematics and other symbols, physical training and development, a rest, and that we concentrate on the inquiry: What are we telling young people directly about the world in which they are to live? What is the world picture we are presenting to their minds? What is the framework of conceptions about reality and about obligation into which the rest of their mental existences will have to be fitted? I am proposing in fact a review of the informative side of education, wholly and solely—informative in relation to the needs of modern life.

And here the fact that I am an educational outsider—which in every other relation would be a disqualification—gives me certain very real advantages. I can talk with exceptional frankness. And I am inclined to think that in this matter of the informative side of education frankness has not always been conspicuous. For what I say I am responsible only to the hearer and my own self-respect. I occupy no position from which I can be dismissed as unsound in my ideas. I follow no career that can be affected by anything I say. I follow, indeed, no career. I have no party, no colleagues or associates who can be embarrassed by any unorthodox suggestions I make. Every schoolmaster, every teacher, nearly every professor must, by the nature of his calling, be wary, diplomatic, compromising—he has his governors to consider, his college to consider, his parents to consider, the local press to consider; he must not say too much nor say anything that might be misunderstood and misunderstood. I can. And so I think I can best serve the purposes of the British Association and this section by taking every advantage of my irresponsibility, being as unorthodox and provocative as I can be, and so possibly saying a thing or two which you are not free to say but which some of you at any rate will be more or less willing to have said.

Now when I set myself to review the field of inquiry I have thus defined, I found it was necessary to take a number of very practical preliminary issues into account. As educators we are going to ask what is the subject-matter of a general education? What do we want known? And how do we want it known? What is the essential framework of knowledge that should be established in the normal citizen of our modern community? What is the irreducible minimum of knowledge for a responsible human being to-day?

I say irreducible minimum—and I do so, because I know at least enough of school work to know the grim significance of the school time-table and of the leaving school age. Under contemporary conditions our only prospect of securing a mental accord throughout the community is by laying a common foundation of knowledge and ideas in the school years. No one believes to-day, as our grandparents—perhaps for most of you it would be better to say great-grandparents—believed, that education had
an end somewhere about adolescence. Young people then left school or college under the imputation that no one could teach them any more. There has been a quiet but complete revolution in people’s ideas in this respect and now it is recognised almost universally that people in a modern community must be learners to the end of their days. We shall be giving a considerable amount of attention to continuation adult and post-graduate studies in this section, this year. It would be wasting our opportunities not to do so. Here in Nottingham University College we have under Professor Peers the only Professorship of Adult Education in England, and the Adult Education Department which is in close touch with the Workers’ Education Association has broadened its scope far beyond the normal range of Adult Education. Our modern idea seems to be a continuation of learning not only for university graduates and practitioners in the so-called intellectual professions, but for the miner, the plough-boy, the taxi-cab driver and the out-of-work, throughout life. Our ultimate aim is an entirely educated population.

Nevertheless it is true that what I may call the main beams and girders of the mental framework must be laid down, soundly or unsoundly, before the close of adolescence. We live under conditions where it seems we are still only able to afford for the majority of our young people, freedom from economic exploitation, teachers even of the cheapest sort and some educational equipment, up to the age of 14 or 15, and we have to fit our projects to that. And even if we were free to carry on with unlimited time and unrestrained teaching resources, it would still be in those opening years that the framework of the mind would have to be made. We have got to see therefore that whatever we propose as this irreducible minimum of knowledge must be imparted between infancy and—at most, the fifteenth or sixteenth year. Roughly, we have to get it into ten years at the outside.

And next let us turn to another relentlessly inelastic packing-case and that is, the school time-table. How many hours in the week have we got for this job in hand? The maximum school hours we have available are something round about thirty, but out of this we have to take time for what I may call the non-informative teaching, the native and foreign language teaching, teaching to read, teaching to write clearly, basic mathematical work, drawing, various forms of manual training, music and so forth. A certain amount of information may be mixed in with these subjects but not very much. They are not what I mean by informative subjects. By the time we are through with these non-informative subjects, I doubt if at the most generous estimate we can apportion more than six hours a week to essentially informative work. Then let us, still erring on the side of generosity, assume that there are 40 weeks of schooling in the year. That gives us a maximum of 240 hours in the year. And if we take ten years of schooling as an average human being’s preparation for life and if we disregard the ravages made upon our school time by measles, chicken-pox, whooping-cough, coronations and occasions of public rejoicing, we are given 2,400 hours as all that we can hope for as our time allowance for building up a coherent picture of the world, the essential foundation of knowledge and ideas, in the minds of our people. The complete framework of knowledge has to be established in
two hundred dozen hours. It is plain that a considerable austerity is indicated for us. We have no time to waste, if our schools are not to go on delivering, year by year, fresh hordes of ignorant, unbalanced, un-critical minds, at once suspicious and credulous, weakly gregarious, easily baffled and easily misled, into the monstrous responsibilities and dangers of this present world. Mere cannon-fodder and stuff for massacres and stampedes.

Our question becomes therefore: 'What should people know—whatever else they don't know? Whatever else we may leave over—for leisure-time reading, for being picked up or studied afterwards—what is the irreducible minimum that we ought to teach as clearly, strongly and conclusively as we know how?'

And now I—and you will remember my rôle is that of the irresponsible outsider, the citizen at large—I am going to set before you one scheme of instruction for your consideration. For it I demand all those precious 2,400 hours. You will perceive the scheme is explicitly exclusive of several contradictory and discursive subjects that now find a place in most curricula, and you will also find doubts arising in your mind about the supply and competence of teachers, a difficulty about which I hope to say something before my time is up. But teachers are for the world and not the world for teachers. If the teachers we have to-day are not equal to the task required of them, then we have to recondition our teachers or replace them. We live in an exacting world and a certain minimum of performance is required of us all. If children are not to be given at least this minimum of information about the world into which they have come—through no fault of their own—then I do think it would be better for them and the world if they were not born at all. And to make what I have to say as clear as possible I have had a diagram designed which I will unfold to you as my explanation unfolds.

You have already noted I have exposed the opening stage of my diagram. You see I make a three-fold division of the child's impressions and the matters upon which its questions are most lively and natural. I say nothing about the child learning to count, scribble, handle things, talk and learn the alphabet and so forth because all these things are ruled out by my restriction of my address to information only. This is what it wants to know. In all these educational matters, there is an element of overlap. As it learns about things and their relationship and interaction its vocabulary increases and its ideas of expression develop. You will make an allowance for that.

And now I bring down my diagram to expose the first stage of positive and deliberate teaching. We begin telling true stories of the past and of other lands. We open out the child's mind to a realisation that the sort of life it is living is not the only life that has been lived and that human life in the past has been different from what it is to-day and on the whole that it has been progressive. We shall have to teach a little about law and robbers, kings and conquests, but I see no need at this stage to afflict the growing mind with dates and dynastic particulars. I hope the time is not far distant when children even of eight or nine will be freed from the persuasion that history is a magic recital beginning 'William the Conqueror, 1066.' Concurrently, we ought to make the weather and the mud
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pie our introduction to what Huxley christened long ago as Elementary Physiography. We ought to build up simple and clear ideas from natural experience.

We start a study of the states of matter with the boiling, evaporation, freezing and so on of water and go on to elementary physics and chemistry. Local topography can form the basis of geography. We shall have to let our learner into the secret that the world is a globe—and for a time I think that has to be a bit of dogmatic teaching. It is not so easy as many people suppose to prove that the world is spherical and that proof may very well be left to make an exercise in logic later on in the education. Then comes biology. Education I rejoice to see is rapidly becoming more natural, more biological. Most young children are ready to learn a great deal more than most teachers can give them about animals. I think we might easily turn the bear, the wolf, the tiger and the ape from holy terrors and nightmare material into sympathetic creatures, if we brought some realisation of how these creatures live, what their real excitements are, how they are sometimes timid, into the teaching. I don’t think that descriptive botany is very suitable for young children. Flowers and leaves and berries are bright and attractive, a factor in aesthetic education, but I doubt if, in itself, vegetation can hold the attention of the young. But directly we begin to deal with plants as hiding-places, homes and food for birds and beasts, the little boy or girl lights up and learns. And with this natural elementary zoology and botany we should begin elementary physiology. How plants and animals live, and what health means for them.

There I think you have stuff enough for all the three or four hundred hours we can afford for the foundation stage of knowledge. Outside this substantial teaching of school hours the child will be reading and indulging in imaginative play—and making that clear distinction children do learn to make between truth and fantasy—about fairyland, magic carpets and seven league boots, and all the rest of it. So far as my convictions go I think that the less young children have either in or out of school of what has hitherto figured as history, the better. I do not see either the charm or the educational benefit of making an important subject of the criminal history of royalty, the murder of the Princes in the Tower, the wives of Henry the Eighth, the families of Edward and James I, the mistresses of Charles II, Sweet Nell of Old Drury, and all the rest of it. I suggest that the sooner we get all that unpleasant stuff out of schools, and the sooner that we forget the border bickerings of England, France, Scotland, Ireland and Wales, Bannockburn, Flodden, Crecy and Agincourt, the nearer our world will be to a sane outlook upon life. In this survey of what a common citizen should know I am doing my best to elbow the scandals and revenges which once passed as English history into an obscure corner or out of the picture altogether.

But I am not proposing to eliminate history from education—far from it. Let me bring down my diagram a stage further and you will see how large a proportion of our treasure of 2,400 hours I am proposing to give to history. This next section represents about 800 to 1,000 pre-adolescent hours. It is the school-boy—school-girl stage. And here the history is planned to bring home to the new generation the reality that the world
is now one community. I believe that the crazy combative patriotism that plainly threatens to destroy civilisation to-day is very largely begotten by the schoolmaster and the schoolmistress in their history lessons. They take the growing mind at a naturally barbaric phase and they inflame and fix its barbarism. I think we underrate the formative effect of this perpetual reiteration of how we won, how our Empire grew and how relatively splendid we have been in every department of life. We are blinded by habit and custom to the way it infects these growing minds with the chronic and nearly incurable disease of national egotism. Equally mischievous is the furtive anti-patriotism of the leftish teacher. I suggest that we take on our history from the simple descriptive anthropology of the elementary stage to the story of the early civilisations. We are dealing here with material that was not even available for the schoolmasters and mistresses who taught our fathers. It did not exist. But now we have the most lovely stuff to hand, far more exciting and far more valuable than the quarrels of Henry II and a Becket or the peculiar unpleasantnesses of King James or King John. Archaeologists have been piecing together a record of the growth of the primary civilisations and the developing rôles of priest, king, farmer, warrior, the succession of stone and copper and iron, the appearance of horse and road and shipping in the expansions of those primordial communities. It is a far finer story to tell a boy or girl and there is no reason why it should not be told. Swinging down upon these early civilisations came first the Semitic-speaking peoples and then the Aryan-speakers. Persian, Macedonian, Roman followed one another, Christendom inherited from Rome and Islam from Persia, and the world began to assume the shapes we know to-day. This is great history and also in its broad lines it is a simple history—upon it we can base a lively modern intelligence, and now it can be put in a form just as comprehensible and exciting for the school phase as the story of our English kings and their terrestrial, dynastic and sexual entanglements. When at last we focus our attention on the British Isles and France we shall have the affairs of these regions in a proper proportion to the rest of the human adventure. And our young people will be thinking less like gossiping court pages and more like horse-riders, seamen, artist-artisans, road-makers and city builders, which I take it is what in spirit we want them to be. Measured by the great current of historical events, English history up to quite recent years is mere hole-and-corner history.

And I have to suggest another exclusion. We are telling our young people about the real past, the majestic expansion of terrestrial events. In these events the little region of Palestine is no more than a part of the highway between Egypt and Mesopotamia. Is there any real reason nowadays for exaggerating its importance in the past? Nothing began there, nothing was worked out there. All the historical part of the Bible abounds in wild exaggeration of the importance of this little strip of land. We were all brought up to believe in the magnificence of Solomon’s temple and it is a startling thing for most of us to read the account of its decorations over again and turn its cubits into feet. It was smaller than most barns. We all know the peculiar delight of devout people when, amidst the endless remains of the great empires of the past, some dubious fragment is found to
confirm the existence of the Hebrews. Is it not time that we recognised the extreme insignificance of the events recorded in Kings and Chronicles, and ceased to throw the historical imagination of our young people out of perspective by an over-emphasised magnification of the history of Judea?

Look at our time-table and what we have to teach. If we give history four-tenths of all the time we have for imparting knowledge that still gives us at most something a little short of 400 hours altogether. Even if we think it desirable to perplex another generation with the myths of the Creation, the Flood, the Chosen People and so forth we haven’t got the time for it—any more than we have the time for the really quite unedifying records of all the Kings and Queens of England and their claims on this and that. No reason why much of that stuff should not be picked up in private reading—by those who like that sort of thing. But so far as the school time-table goes we are faced with a plain alternative. One thing or the other. Great history or hole-and-corner history? The story of mankind or the narrow, self-righteous, blinkered stories of the British and the Jews?

There is a lot more we have to put into the heads of our young people over and above History. It is the main subject of instruction but even so, it is not even half of the informative work that ought to be got through in this school stage. We have to consider the collateral subject of geography and a general survey of the world. We may have a little map-making here, but I take it what is needed most are reasonably precise ideas of the various types of country and the distinctive floras and faunas of the main regions of the world. We do not want our budding citizens to chant lists of capes and rivers, but we do want them to have a real picture in their minds of the Amazon forests, the pampas, the various phases in the course of the Nile, the landscape of Labrador and so on, and also we want something like a realisation of the sort of human life that is led in these regions. We have enormous resources now in cheap photography, in films and so forth, that even our fathers never dreamt of—to make all this vivid and real. New methods are needed to handle these new instruments but they need not be overwhelmingly costly. And also our new citizen should know enough of topography to realise why London and Rio and New York and Rome and Suez happen to be where they are and what sort of places they are.

Geography and history run into each other in this respect and, on the other hand, Geography reaches over to Biology. Here again our schools lag some fifty years behind contemporary knowledge. The past half-century has written a fascinating history of the succession of living things in time and made plain all sorts of processes in the prosperity, decline, extinction and replacement of species. We can sketch the wonderful and inspiring story of life now from its beginning. Moreover, we have a continually more definite account of the sequence of sub-man in the world and the gradual emergence of our kind. This is elementary, essential, interesting and stimulating stuff, and it is impossible to consider anyone a satisfactory citizen who is still ignorant of that great story.

And finally, we have the science of inanimate matter. In a world of machinery, optical instruments, electricity, radio and so forth we want to
lay a sound foundation of pure physics and chemistry upon the most modern lines—for everyone. Some of this work will no doubt overlap the mathematical teaching. And finally, to meet awakening curiosity and take the morbidity out of it, we have to tell our young people and especially our young townspeople, about the working of their bodies, about reproduction and about the chief diseases, enfeeblements and accidents that lie in wait for them in the world.

That I think completes my summary of all the information we can hope to give in the lower school stage. And as I make it I am acutely aware of your unspoken comment. With such teachers as we have! Well, I think that it is a better rule of life, first to make sure of what you want and then set about getting it, rather than to consider what you can easily safely and meanly get, and then set about reconciling yourself to it. I admit we cannot have a modern education without a modernised type of teacher. Everything I am saying now implies a demand for more and better teachers—with better equipment. And these teachers will have to be kept fresh. It is stipulated in most leases that we should paint our houses outside every three years and inside every seven years, but nobody ever thinks of doing up a school teacher. There are teachers at work in this country who haven't been painted inside for fifty years. They must be damp and rotten. Two-thirds of the teaching profession now is in urgent need of being either reconditioned or superannuated. In this advancing world the reconditioning of both the medical and the scholastic practitioner is becoming a very urgent problem indeed, but it is not one that I can deal with here. Presently this section will be devoting its attention to adult education and then I hope the whole question of professional and technical refreshment will be ventilated.

And there is another matter also closely allied to this question of the rejuvenation of teachers, at which I can only glance now, and that is the bringing of school books up to date. In this informative section of school work there is hardly a subject in which knowledge is not being vigorously revised and added to. Our school work does not follow up contemporary digesting. Still less do our school libraries. They are ten, fifteen years out of date with much of their information. Our prison libraries by the by are even worse. I was told the other day of a virtuous prisoner who wanted to improve his mind about radio. The prison had a collection of technical works made for such an occasion and the latest book on radio was dated 1920. There is, I believe, an energetic New School Books Association at work in this field, doing what it can to act in concert with those all too potent authorities who frame our examination syllabuses. I am all for burning old school books. Some day perhaps we shall have school books so made that at the end of five years, let us say, they will burst into flames and inflict severe burns upon any hands in which they find themselves. But at present that is perhaps—Utopian. It is even more applicable to the next stage of knowledge to which we are now coming.

This stage represents our last thousand hours and roughly I will call it the upper form or upper standard stage. It is really the closing phase of the available school period. Some of the matter I have marked for the history of this grade might perhaps be given in grade B and vice versa.
We have still a lot to do if we are to provide even a skeleton platform for the mind of our future citizen. He has still much history to learn before his knowledge can make an effective contact with his duties as a voter. You see I am still reserving four-tenths of the available time, that is to say nearly 400 hours for history. But now we are presenting a more detailed study of such phenomena as the rise and fall of the Ottoman Empire, the rise of Russia, the history of the Baltic, the rise and fall of the Spanish power, the Dutch, the first and second British Empires, the belated unifications of Germany and Italy. Then as I have written we want our modern citizen to have some grasp of the increasing importance of economic changes in history and the search for competent economic direction and also of the leading theories of individualism, socialism, the corporate state, communism.

For the next five-and-twenty years now the ordinary man all over the earth will be continually confronted with these systems of ideas. They are complicated systems with many implications and applications. Indeed they are aspects of life rather than systems of ideas. But we send out our young people absolutely unprepared for the heated and biased interpretations they will encounter. We hush it up until they are in the thick of it. The most the poor silly young things seem able to make of it is to be violently and self-righteously Anti-something or other. Anti-Red, Anti-Capitalist, Anti-Fascist. The more ignorant you are the easier it is to be an Anti. To hate something without having anything substantial to put against it. A special sub-section of history in this grade should be a course in the history of War, which is always written and talked about by the unwary as though it had always been the same, while as a matter of fact—except for its violence—it has changed profoundly with every change in social, political and economic life. Clearly parallel to this history our young people need now a more detailed and explicit acquaintance with world geography, with the different types of population in the world and the developed and undeveloped resources of the globe. The devastation of the world's forests, the replacement of pasture by sand deserts through haphazard cultivation, the waste and exhaustion of natural resources, coal, petrol, water, that is now going on, the massacre of important animals, whales, penguins, seals, food fish, should be matters of universal knowledge and concern.

Then our new citizens have to understand something of the broad elements in our modern social structure. They should be given an account of the present phase of communication and trade, of production and invention and above all they need whatever plain knowledge is available about the conventions of property and money. Upon these conventions human property stands, and the efficiency of their working is entirely dependent upon the general state of mind throughout the world. We know now that what used to be called the inexorable laws of political economy and the laws of monetary science, are really no more than rash generalisations about human behaviour, supported by a maximum of pompous verbiage and a minimum of scientific observation. Most of our young people come on to adult life, to employment, business and the rest of it, blankly ignorant even of the way in which money has changed slavery and serfdom into wages employment and how its fluctuations in
value make the industrial windmills spin or flag. They are not even warned of the significance of such words as inflation or deflation, and the wage earners are the helpless prey at every turn towards prosperity of the savings-snatching financier. Any plausible monetary charlatan can secure their ignorant votes. They know no better. They cannot help themselves. Yet the subject of property and money—together they make one subject because money is only the fluid form of property—is scarcely touched upon in any stage in the education of any class in our community. They know nothing about it; they are as innocent as young lambs and born like them for shearing.

And now here you will see I have a very special panel. This I have called Personal Sociology. Our growing citizen has reached an age of self-consciousness and self-determination. He is on the verge of adolescence. Moral training does not fall within the scope of the informative content of teaching. Already the primary habits of truthfulness, frankness, general honesty, communal feeling, helpfulness and generosity will or will not have been fostered and established in the youngster's mind by the example of those about him. A mean atmosphere makes mean people, a too competitive atmosphere makes greedy, self-glorifying people, a cruel atmosphere makes fierce people, but this issue of moral tone does not concern us now here. But it does concern us that by adolescence the time has arrived for general ideas about one's personal relationship to the universe to be faced. The primary propositions of the chief religious and philosophical interpretations of the world should be put as plainly and impartially as possible before our young people. They will be asking those perennial questions of adolescence—whence and why and whither. They will have to face, almost at once, the heated and exciting propagandas of theological and sceptical partisans—pro's and anti's. As far as possible we ought to provide a ring of clear knowledge for these inevitable fights. And also, as the more practical aspect of the question, What am I to do with my life? I think we ought to link with our general study of social structure a study of social types which will direct attention to the choice of a métier. In what spirit will you face the world and what sort of job do you feel like? This subject of Personal Sociology as it is projected here is the school equivalent of a confirmation class. It says to everyone: 'There are the conditions under which you face your world.' The response to these questions, the determination of the will, is however not within our present scope. That is a matter for the religious teacher, for intimate friends and for the inner impulses of the individual. But our children must have the facts.

Finally, you will see that I have apportioned some time, roughly two-tenths of our 1,000 hours, in this grade to the acquisition of specialised knowledge. Individuality is becoming conscious of itself and specialisation is beginning.

Thus I budget, so to speak, for our 2,400 hours of informative teaching. We have brought our young people to the upper form, the upper standard. Most of them are now going into employment or special training and so taking on a rôle in the collective life. But there remain some very essential things which cannot be brought into school teaching, not through any want of time, but because of the immaturity of the growing mind. If
we are to build a real modern civilisation we must go on with definite informative instruction into and even beyond adolescence. Children and young people are likely to be less numerous proportionally in the years ahead of us in all the more civilised populations and we cannot afford to consume them in premature employment after the fashion of the preceding centuries. The average age of our population is rising and this involves an upward extension of education. And so you will see I suggest what I call an undergraduate or continuation school, Grade D, the upper adolescent stage, which I presume will extend at last to every class in the population, in which at least half the knowledge acquired will be specialised in relation to interest, aptitude and the social needs of the individual. But the other half will have to be unspecialised, it will have to be general political education. Here particularly comes in that education for citizenship to which this educational section is to give attention later. It seems to me altogether preposterous that nowadays our educational organisation should turn out new citizens who are blankly ignorant of the history of the world during the last twenty-five years, who know nothing of the causes and phases of the Great War and are left to the tender mercies of freakish newspaper proprietors and party organisers for their ideas about the world outlook, upon which their collective wills and actions must play a decisive part.

Social organisation is equally a matter for definite information. 'We are all socialists nowadays.' Everybody has been repeating that after the late Lord Rosebery for years and years. Each for all and all for each. We are all agreed upon the desirability of the spirit of Christianity and of the spirit of Democracy, and that the general interest of the community should not be sacrificed to Private Profit. Yes—beautiful, but what is not realised is that Socialism in itself is little more than a generalisation about the undesirability of irresponsible ownership and that the major problem before the world is to devise some form of administrative organisation that will work better than the scramble of irresponsible owners. That form of administrative organisation has not yet been devised. You cannot expropriate the private adventurer until you have devised a competent receiver for the expropriated industry or service. This complex problem of the competent receiver is the underlying problem of most of our constructive politics. It is imperative that every voter should have some conception of the experiments in economic control that are in progress in Great Britain, the United States of America, Italy, Germany, Russia and elsewhere. Such experiments are going to affect the whole of his or her life profoundly. So, too, are the experiments in monetary and financial organisation. Many of the issues involved go further than general principles. They are quantitative issues, questions of balance and more or less. A certain elementary training in statistical method is becoming as necessary for anyone living in this world of to-day as reading and writing. I am asking for this much contemporary history as the crowning phase, the graduation phase of our knowledge-giving. After that much foundation, the informative side of education may well be left to look after itself.

Speaking as a teacher of sorts myself, to a gathering in which teachers probably predominate, I need scarcely dilate upon the fascination of diagram drawing. You will understand how reluctant I was to finish off
at Grade D and how natural it was to extend my diagram to two more
grades and make it a diagram of the whole knowledge organisation of a
modern community. Here then is Grade E, the adult learning that goes
on now right through life, keeping oneself up to date, keeping in touch
with the living movements about us. I have given a special line to those
reconditioning courses that must somehow be made a normal part in the
lives of working professional men. It is astonishing how stale most
middle-aged medical men, teachers and solicitors are to-day. And beyond
Grade E I have put a further ultimate grade for the fully adult human
being. He or she is learning now, no longer only from books and newspa-
pers and teachers, though there has still to be a lot of that, but as a worker
with initiative, making experiments, learning from new experience, an
industrialist, an artist, an original writer, a responsible lawyer, an adminis-
trator, a statesman, an explorer, a scientific investigator. Grade F
accumulates, rectifies, changes human experience. And here I bring in
an obsession of mine with which I have dealt before the Royal Institute
and elsewhere. You see, indicated by this flight of arrows, the rich
results of the work of Grade F flowing into a central world-encyclopedic-
organisation, where it will be continually summarised, clarified, and whence
it will be distributed through the general information channels of the world.
So I complete my general scheme of the knowledge organisation of a
modern community and submit it to you for your consideration.
I put it before you in good faith as a statement of my convictions. I do
not know how it will impress you and I will not anticipate your criticisms.
It may seem improbably bold and 'Utopian.' But we are living in a
world in which a battleship costs £8,000,000, in which we can raise an
extra 400 million for armaments with only a slight Stock Exchange qualm,
and which has seen the Zeppelin, the radio, the bombing aeroplane come
absolutely out of nothing since 1900. And our schools are drooling along
very much as they were drooling along 37 years ago.
There is only one thing I would like to say in conclusion. Please do
me the justice to remember that this is a project for Knowledge Organisa-
tion only and solely. It is not an entire scheme of education I am putting
before you. It is only a part and a limited part of education—the factual
side of education—I have discussed. There are 168 hours in a week and
I am dealing with the use of rather less than six during the school year of
less than 40 weeks—for 10 years. It is no good saying as though it was
an objection either to my paper or to me, that I neglect or repudiate
spiritual, emotional and aesthetic values. They are not disregarded, but
they have no place at all in this particular part of the educational scheme.
I have said nothing about music, dancing, drawing, painting, exercise
and so on and so forth. Not because I would exclude them from educa-
tion but because they do not fall into the limits of my subject. You no
more want these lovely and elementary things mixed up with a conspectus
of knowledge than you want playfulness in an ordnance map or perplexing
whimsicality on a clock face. You have the remaining 162 hours a week
for all that. But the spiritual, emotional, aesthetic lives our children are
likely to lead, will hardly be worth living, unless they are sustained by
such a clear, full and sufficient backbone of knowledge as I have ventured
to put before you here.
SECTION M.—AGRICULTURE.

STATE INTERVENTION IN AGRICULTURE

ADDRESS BY

J. M. CAIE, M.A., B.L., B.Sc. (Agr.),

PRESIDENT OF THE SECTION.

Two years ago, Dr. Venn, who presided over this section during the meetings of the Association at Norwich, delivered a masterly address on 'The Financial and Economic Results of State Control in Agriculture.' To-day my subject is 'State Intervention in Agriculture,' and for any apparent infringement of his copyright I tender him an apology. The reasons for my choice are twofold. In the first place, it is the custom, very rightly, for those who have the honour to be presidents of sections to deal with matters of which they have made a special study or have some first-hand experience. Being a mere administrative official and not a scientific worker, as the term is generally understood, I must, if I am to follow the excellent precedent, restrict myself to the field in which I happen to work.

My second reason is less personal. In the economic and political conditions of the world in recent years the importance of agriculture in the life of the State, not only in this country but elsewhere, has received growing recognition. That recognition may not always have been quite spontaneously accorded; rather indeed it has been extorted by economic and social forces of a most complex and compelling kind. Over-production and under-consumption, of which we have heard so much, have thrust agriculture to the middle of the stage and into the beam of a pale blue limelight. The agriculturist, cast too often for the part of the starving orphan, has raised his voice, now in lamentation, now in vituperation, calling on the State for help, or fair play, or protection against some industrial ogre or foreign invader. And the State, moved by his 'exceeding bitter cry,' has played the part sometimes of the fairy godmother, sometimes of the heavy father, and sometimes, so the farmer may say, of the deaf and cunning uncle. But never probably, save in the war years, have the State and the farmers been so closely interested in each other. And that is the second reason for my choice, which I have made in the hope that possibly a general survey of the relation of State and farmer might be of some little value. In attempting that survey, I believe that, despite the title of the paper, I shall trespass little if at all on that part of the subject which was examined so penetratingly and expounded so luminously by Dr. Venn.
One cautionary statement I must make before I go further. When speaking here, I do so entirely as a private individual and not as an official; the department to which I belong is in no way responsible for this address and must not be held as necessarily agreeing with anything it contains.

For purposes of definition, it is desirable to show, as concisely as possible, the part occupied by agriculture in the economic structure of the State. The following tables give the essential facts relating to areas, holdings and populations, the output of food from our farms, and the contribution they make to the total food consumption of the people. As a matter of interest, corresponding figures are given for two other countries, Denmark and Norway, which are more agricultural and less industrial than Great Britain. These tables have been very kindly prepared for me by Mr. W. H. Senior. Most of the data relating to Denmark have been obtained from Professor O. H. Larsen, and those for Norway from Professor Paul Borgedal; I am much indebted to these gentlemen for their kindness and courtesy.

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<tr>
<td>Number of agricultural holdings.</td>
<td>(Over 1 acre.) 455,185 (1935).</td>
<td>(Over 1 ha., i.e. 2.5 acres.) 204,003 (1935). 7,975,000 acres (1935) (approx.).</td>
<td>(Over 0.5 ha., i.e. 1.25 acre.) 208,550 (1930). 2,500,000 acres (1930) (approx.).</td>
</tr>
<tr>
<td>Total population.</td>
<td>44,790,485 (1930) About 1.5.</td>
<td>3,550,656 (1930) About 0.45.</td>
<td>2,814,194 (1930) About 1.1.</td>
</tr>
<tr>
<td>Number of people per acre of cultivated land.</td>
<td>5.7% (Workers of total occupied population.)</td>
<td>29% (Workers of total occupied population.)</td>
<td>30% (All persons.)</td>
</tr>
<tr>
<td>Percentage of population in agriculture.</td>
<td></td>
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The chief facts to note here are the familiar ones, brought out in the last two lines, that in Great Britain the number of persons per acre of cultivated land, 1.5, is relatively high, being three times as many as in Denmark and nearly half as many again as in Norway, while the percentage of the population engaged in British agriculture, about 6 per cent., is very low as compared with 20 or 30 per cent. in the other two countries. Notwithstanding the importance and value of our industrial development, this figure of 6 per cent. has social and other implications which have exercised the minds of many people and need not be elaborated here.

This table shows that, as is again fairly well known, the products of our animal husbandry account for a very large proportion of the output of
Our land, about 72 per cent. The proportions in Denmark and Norway are even higher, and incidentally it may be remarked that in Scotland the

**Agricultural Output, 1935.**

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<tr>
<td></td>
<td>£ Million.</td>
<td>%</td>
<td>£ Million.</td>
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<tr>
<td><strong>Meat:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>39·0</td>
<td>16·2</td>
<td>7·4</td>
</tr>
<tr>
<td>Veal</td>
<td>3·1</td>
<td>1·3</td>
<td>0·7</td>
</tr>
<tr>
<td>Mutton and lamb</td>
<td>22·2</td>
<td>9·2</td>
<td>0·1</td>
</tr>
<tr>
<td>Pork and bacon</td>
<td>20·8</td>
<td>8·7</td>
<td>25·8</td>
</tr>
<tr>
<td><strong>Sub total</strong></td>
<td>85·1</td>
<td>35·4</td>
<td>33·3</td>
</tr>
<tr>
<td><strong>Dairy and poultry produce, etc.:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td>53·9</td>
<td>22·4</td>
<td>30·2</td>
</tr>
<tr>
<td>Butter</td>
<td>5·1</td>
<td>2·1</td>
<td>—</td>
</tr>
<tr>
<td>Cheese</td>
<td>2·8</td>
<td>1·2</td>
<td>—</td>
</tr>
<tr>
<td>Cream</td>
<td>0·7</td>
<td>0·3</td>
<td>—</td>
</tr>
<tr>
<td>Poultry</td>
<td>5·6</td>
<td>2·3</td>
<td>6·8</td>
</tr>
<tr>
<td>Eggs.</td>
<td>17·8</td>
<td>7·4</td>
<td>—</td>
</tr>
<tr>
<td>Wool</td>
<td>1·8</td>
<td>0·8</td>
<td>—</td>
</tr>
<tr>
<td>Horses</td>
<td>0·1</td>
<td>0·0</td>
<td>1·2</td>
</tr>
<tr>
<td><strong>Live stock and livestock products</strong></td>
<td>172·9</td>
<td>71·9</td>
<td>71·5</td>
</tr>
<tr>
<td>Crops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereal, grain and straw</td>
<td>13·3</td>
<td>5·5</td>
<td>5·3</td>
</tr>
<tr>
<td>Potatoes</td>
<td>14·9</td>
<td>6·2</td>
<td>4·2</td>
</tr>
<tr>
<td>Other crops</td>
<td>11·4</td>
<td>4·8</td>
<td>—</td>
</tr>
<tr>
<td>Fruit, vegetables, flowers and honey</td>
<td>27·9</td>
<td>11·6</td>
<td>—</td>
</tr>
<tr>
<td><strong>Total crops, etc.</strong></td>
<td>67·5</td>
<td>28·1</td>
<td>9·5</td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td>240·4</td>
<td>100·0</td>
<td>81·0</td>
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</tbody>
</table>
to those who are responsible for shaping the agricultural policy of the country. The facts it contains and the agricultural conditions it illustrates are indeed of fundamental importance. These facts result from our soil, our climate and the consequent experience and aptitude of our farmers; they are not entirely unalterable, but any policy of improvement, development or control must primarily be based upon them.

The value of the agricultural output per acre of cultivated land is, in round figures, £8 in Great Britain and Norway, and £11 in Denmark. In contrast to this, the annual output per person in British agriculture is about £200, and in Danish about £150.

SELF-SUFFICIENCY IN REGARD TO IMPORTANT PRODUCTS.

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<tr>
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<tr>
<td></td>
<td>1935.</td>
<td>1935.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Imported.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef and veal</td>
<td>53</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Mutton and lamb</td>
<td>45</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Pork and bacon</td>
<td>50</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Poultry</td>
<td>(G.B.) 78</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Eggs</td>
<td>66</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Milk (liquid)</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese</td>
<td>30</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Butter</td>
<td>10</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>26</td>
<td>7</td>
<td>33</td>
</tr>
<tr>
<td>Barley</td>
<td>46</td>
<td>95</td>
<td>67</td>
</tr>
<tr>
<td>Oats</td>
<td>91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td>96</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

N.B.—Estimates for United Kingdom and Denmark based on quantities, those for Norway on values.

The figures in this third table need little comment and are in a sense a corollary to those in the two previous tables. As regards animal products, the two Scandinavian countries are self-supporting, whereas we produce only about, very roughly, half our requirements of the various kinds of meat, nearly four-fifths of our poultry and two-thirds of our eggs. We produce all the liquid milk we consume, but only 30 per cent. of our cheese and 10 per cent. of our butter. Of wheat we import about three-fourths of our annual ration and of barley fully half, but we grow over nine-tenths of our oats and nearly all the potatoes we eat.

So much for agriculture as a producer. What about agriculture as a
buyer of the products of other industries? Only a rough and possibly unreliable estimate can be given. According to the farm accounts obtained for 2,450 Scottish farms, of different kinds and in different districts, for the years 1934-35, the estimated expenditure on building materials, implements and machinery, electricity, fuel, chemicals, fertilisers, etc., amounted to from 14s. to 20s. per acre of cultivated land. Admittedly this is a small sample on which to base a generalisation, but, taking it for what it is worth, it would represent a gross total of from twenty to thirty million pounds for the whole country. The corresponding figures per acre are for Denmark 26s. (based on 810 farm accounts for 1935-36), and for Norway from 12s. to 21s.

It may be noted that no allowance is made for the personal purchases of the agricultural population, which presumably would be made, more or less, no matter what the employment of the people might be. The figures represent the purchases of the agricultural industry as such, and show to what extent it is the customer of other industries.

The word "intervention" is sometimes used as being equivalent to control. In this paper it has a wider meaning and is intended to cover the various ways in which the action of the State may impinge on agriculture—the 'impact' of the State on agriculture, to borrow the word employed by Sir Josiah Stamp in his presidential address to the Association last year. Intervention, according to this definition, falls broadly into three categories:

1. Control, i.e. statutory compulsion, enforced by penalties.
2. The statutory provision of means by which agriculturists may take voluntary action to do certain things and, in the event of such action, to compel a minority to conform to the wishes of a majority.
3. The giving of direct or indirect assistance, financial, advisory, protective, etc.

Let us first consider control. A complete stranger visiting these islands might receive an impression, perhaps from an agricultural newspaper, or a farmer’s meeting, that the agriculturists were oppressed by the rules and regulations of a government that joyed in tyranny, aided by a horde of official tormentors who not only battened on the sufferers but were often accused of being the real inventors of the legislative boots and thumb-screws. The depth and permanence of that impression would depend in the first place on where the stranger came from. If he came from certain European states, the impression might be fleeting; comparing conditions here with those to which he had been accustomed, he might soon say, ‘Here is peace: here indeed is freedom.’ And if he looked a little under the surface and studied the relation of state and people in this democratic country, he would discover that a government, no matter how inspired by good intentions and a large majority, could rarely if ever pass a law that was unacceptable to the general community, agricultural or other, or, if it succeeded in doing so, would find it very hard to administer it effectively. To legislate in advance of public opinion is no easy matter. Those who have to do with the formulation of legislative proposals, subsequently to be embodied in parliamentary bills, know that an Act of Parliament does not emerge suddenly, fully armed from the
head of love. Usually it is only after prolonged discussion and consultation with organisations and individuals that a bill takes shape and gets into sufficient training, so to speak, to run the gauntlet of parliamentary criticism. It is true that a government, having to weigh as best it can the conflicting claims and interests of different industries and sections of the population, may not always meet the wishes of agriculture; but on examination it will generally be found that while it may withhold desired benefits, it seldom if ever attempts to impose an agricultural law to which there is wide and strong objection throughout the industry. The contribution of the civil servant, the so-called bureaucrat, to the legislative process may be one of labour and anxiety, but to call him the real villain of the piece is to flatter him and to ignore the fundamental and very real principle of ministerial responsibility. The British civil servant is truly a servant, informing and advising so far as he reasonably may, but always obeying loyally the government of the day, no matter what its colour or its political philosophy may be. And, if I may say so, British Ministers, of whatever party, do not fail to accord to the Civil Service a corresponding loyalty and that protection from any party criticism without which the Service's impartiality and devotion to duty could not be maintained. The system is the product of a long evolutionary process; it may have defects, but it is at any rate the fruit of the political genius of the British nation. This, however, is something of a digression.

If our foreign visitor were historically minded, he might be interested to look into the past to see how present measures of control compare with some of those to which agriculture was subjected in former days. I have no time in this paper, nor have I the qualifications, to accompany him in any comprehensive study of the subject. One can but glance at a few of the more noticeable instances, in some cases forming precedents or foundations for later legislation. In his English Farming Past and Present Lord Ernle says that, 'In the early stages of history, the law itself was powerless to protect individual independence or to safeguard individual rights. Agriculture like other industries was therefore organised on principles of graduated dependence and collective responsibility. Mediaeval manors in fact resembled trade guilds. . . .'

These continued until the local and gradual break up of the manorial organisation of agricultural labour was accelerated by the Black Death (1348-49). Labour became so scarce that panic wages were asked and paid until in 1349 by Royal Proclamation all men and women 'bond or free,' unless tilling their own land or engaged in merchandise or in some other craft, were compelled to work on the land where they lived at the rate of wages current in 1346. Here, nearly 600 years ago, was wages regulation of a pretty drastic kind, but it was a maximum that was fixed, not a minimum. Later on, in 1563, we find another notable effort to control the labour market in the Statute of Apprentices, which enacted, inter alia, that all persons between 12 and 60, not exempted by the statute, could be compelled to labour in husbandry and that masters unduly dismissing servants were fined and that servants unduly leaving masters were imprisoned. It also stated hours of labour and provided for the fixing of wages by Justices of the Peace.
The story of land enclosure is well known and need only be mentioned as an illustration of State intervention, operating first in one direction and afterwards in another. In the sixteenth century, land enclosure, involving the break-up of mediaeval agrarian partnerships and a substitution of private enterprise for the collective efforts of village associations, was opposed and partly arrested by legislation; in the eighteenth century it was a penal offence for any person over the age of six not to wear on Sundays and holydays a cap made of English cloth. Later, in 1666, the law did not stop short even at the gates of the churchyard, for it required that the dead should be buried in shrouds of home-grown wool. In passing, it may be noted that about the same time the Government, 'for the sake of multiplying seamen,' had ordained fast-days on which only fish was to be eaten. With precedents of that sort before us, we are almost tempted to long for an Act making the consumption of oatmeal, milk and herrings obligatory, and the possession of a tin-opener a criminal offence; it would solve several current problems of Scottish agriculture and fisheries.

Legislation of another kind prevailed throughout the eighteenth century, when home production was encouraged by the placing of a duty on the importation of foreign corn and the payment of a bounty on exported corn, combined, however, with frequent prohibitions of exports. Similar laws were enacted to encourage the raising of cattle, and importations from Ireland were prohibited. But legislation, says Lord Ernle, did not raise prices; it only succeeded in maintaining them. Increased production at home counteracted the effect which limitation of imports was designed to produce. It is unnecessary here to retell the story of the corn laws and of their repeal, or to touch on more recent fiscal controversies.

The earlier instances of State intervention that I have cited were all English, but the Scottish parliament also provides us with some interesting examples. With regard to labour, the extinction of serfdom having been considered productive of indolence, a statute of 1424 required cottage holders to perform a certain amount of labour on the land, a provision for which we have had an English parallel. At almost the same date, 1426, we find parliament taking partial control of cropping. To secure a greater variety of crop than the oats and bere which were chiefly cultivated, it was enacted that every man tilling with a plough of eight oxen should sow every year at least a firlot of wheat, half a firlot of peas and forty beans, 'under the pain of ten shillings.' At a much later date, 1703, a curious Act relating to cultivation was passed, forbidding any
butcher to have more than one acre of land for grazing unless it be tilled annually, under penalty of £100 Scots for each offence, loss of the cattle found grazing and loss of the freedom of the burgh. Public health and amenity were not overlooked, for to improve the aspect of the country, check malaria and provide shelter, all freeholders were required (1457) to plant on their land trees, hedges, and broom. Nearly two hundred and fifty years later (1695) an Act for the preservation of meadow lands and pasturages near sandhills forbids the pulling up of bent, juniper and broom.

The necessity of keeping down weeds was recognised in the statute which required the cleansing of land from 'guld,' i.e. marigold. The Act, with a touch of humour now sadly lacking in modern statutes, sets forth that anyone who planted 'guld' deserved punishment as amply as if he had led an army against the king and barons.

Pig-feeding was discouraged. No burgess could permit swine to remain in the fields without a keeper and they had to be kept out of plantations and hunting ground, while it was decreed by Parliament that the owner of a hog which made a hole in a meadow or open place should be compelled to fill the hole with grains of wheat.

Security of tenure is a subject of which we still hear. In the middle of the fifteenth century (1449) there was passed what might almost be called the first of the Agricultural Holdings Acts. It provided that 'for the safetie and favour of the puir papil that labouris the grunde, that thay and all utheris sall remaine with their tackes unto the ischew of their termes, quhais hands that ever thay landis cum to.' In other words, a change of ownership of the lands did not involve the dispossession of the sitting tenants. Our present law restricting the period for 'making muirburn,' i.e. heather burning, goes back, with some difference of the dates, to at least 1400.

Storage of grain, a measure now advocated by some for purposes of defence, was not considered desirable in the fifteenth and sixteenth centuries, for in 1449 it was enacted that 'to prevent dearth,' no old stacks of corn were to be kept in the yard after Christmas; in 1452 the date was extended to the end of May; and in 1563 to the 10th of July.

These few examples of how in the past the State has laid its hand, sometimes heavily, sometimes helpfully, on agriculture are obviously very far from exhaustive and are not intended in any way to constitute a historic survey. They have been selected almost at random, to show that intervention—call it interference if you will—however much we may think we suffer from it to-day, is no new thing. You will observe that the intervention was almost all of the compulsory kind, the single exception among the instances quoted being the Scottish Act conferring a degree of security of tenure. My second category is not represented and there is no bestowal of direct benefits such as subsidies, etc.

Having glanced at some precedents, let us consider the present state of affairs. We are all, of course, subject to State control of various kinds; we must educate our children, subject to State control of various kinds; we must educate our children, pay income-tax, drive our cars carefully, refrain from buying or selling certain goods after certain hours, and so on. Some people think we have far too much of such control,
others find their yearnings still unsatisfied, and are eager to kiss, or to see
others kissing, almost any new rod. There are, indeed, probably few of
us who could not mention some objectionable thing that other people
ought not to be allowed to do. But here we are considering not the common
burdens that have been laid upon all citizens, but only those special ones
that have been imposed upon the agriculturist as such. I am not going to
trouble you with a catalogue of Acts of Parliament, nor need I refer to
the various compulsive or restrictive measures of war-time. It will be
sufficient to mention some of the existing laws in my first category that
come most readily to mind.

The farmer is bound to furnish to the Government annual statistical
returns of his crops and live stock. For many years the returns were
made voluntarily, but since 1925 they have been compulsory. The filling
up of forms is one of life’s minor worries, but no one could say that the
compilation of accurate agricultural statistics is not essential for the proper
understanding of many of the major agricultural questions with which
the Government and the farmers themselves have to deal.

The Contagious Diseases of Animals Acts, administered for the whole
of Great Britain by the Ministry of Agriculture and Fisheries, may at
times interfere seriously with the activities of the farmer as a stock-
owner, but without them he would undoubtedly be exposed to vastly
greater and possibly catastrophic losses. Similarly, the Destructive
Insects and Pests Acts may occasionally hamper him as a crop grower,
but on the other hand they afford him protection with which he would
not willingly dispense. These two laws are in fact more protective than
restrictive, and I have never heard any one suggest that they should be
repealed.

As a breeder of horses and cattle, the farmer must conform to the
requirements of the Horse Breeding Act and the Licensing of Bulls Act,
which are designed to prevent the use of inferior sires. Here again
agricultural opinion is, in general, entirely on the side of the law; represen-
tations have, in fact, been received from responsible quarters that the
principle should be extended to pig-breeding.

A statutory system of prescribing and enforcing the payment of mini-
num wages to agricultural workers has been operative in England since
1924, and Parliament has recently passed an Act introducing a similar
system into Scotland, where at the time of the passing of the English Act,
and for several years after, the workers themselves, as well as the farmers,
were opposed to having such legislation. Here perhaps we come to a
subject not quite free from controversy. But if it be accepted that with-
out such legislation there is a danger that the pay of the worker might fall
below the amount necessary to maintain him and his family in a reasonable
degree of comfort, there are few who would deny its justice. Criticism of
the law has been based not, I think, on this ground, but rather on the ground
that certain other steps should be taken to enable the farmer, in his
economic difficulties of recent years, to pay a satisfactory wage. The
criticism, so to speak, has been consequential rather than direct; there
has been little opposition to the fundamental principle embodied in the
Acts.
The Corn Production Act is remembered with mingled feelings. One solitary vestige of it remains in operation, the section requiring the destruction of certain specified weeds. As these are weeds which, if unchecked, may spread far and wide, there need be little sympathy with the delinquent who permits them to grow, to the detriment of his fellow-farmers.

Under the Milk and Dairies Acts, the dairy farmer, in the interests of public health, has to conform to certain standards of cleanliness, accommodation, equipment, etc.

Certain restrictions, not very onerous, are laid on farmers by such Acts as the Animal Anaesthetics Act, the Dangerous Drugs Act, the law relating to Heather Burning in Scotland, the Slaughter of Animals Act, and some others which may occur to you.

Whether the State presses more or less heavily on agriculture than on other businesses, e.g. shipping, mining, manufacture, shops, railways, etc., I am not in a position to estimate; but later in this paper I shall venture on the opinion that the farmer is perhaps fortunate in that the hand of the law does not hold him in a tighter grasp than it does at present.

I come now to my second category of State intervention: that in which the State does not at first hand compel or prohibit, but gives farmers the opportunity to organise themselves for certain purposes and, should the necessary majority of producers decide to avail themselves of the opportunity, empowers them to secure conformity by the minority and to impose penalties on recalcitrant or erring individuals. The Agricultural Marketing Acts are the only laws that come strictly within this definition, although the Agricultural Produce (Grading and Marking) Act is similar in that the adoption of the National Mark under it is permissive, but when it is adopted it conveys a statutory guarantee of quality, with penalties for mis-use. As you know, the Marketing Acts are a recent institution in this country. Hitherto, agricultural co-operation for the marketing of agricultural products had been on an entirely voluntary basis, with the advantages and disadvantages inherent in such a system: on the one hand, complete freedom of the individual, and on the other the danger that the desires of a majority might in practice be frustrated by a minority who, for various reasons—personal gain, short-sightedness, secretiveness, love of individual independence—were unwilling to observe the rules and limitations necessary to secure successful collective action. But under the Marketing Acts, co-operation can be fortified with some very effective artillery. Fundamentally, however, the principle is still voluntary and the system democratic. Unless the required majority of the producers of a certain commodity vote in favour of the marketing scheme submitted to them at a poll, the Government has no power to impose a scheme upon them. In Scotland, for example, two raspberry marketing schemes have been rejected at the poll, and there the matter ended. And should a scheme be adopted and approved by Parliament, it is administered by a Board elected by the registered producers themselves.

The need for improved marketing methods in this country is widely, if not universally, admitted; the economic dangers and disadvantages to the farmers of the indiscriminate sale of their goods in haphazard
quantities and of irregular quality by hosts of unrelated producers have been only too apparent in the past; and the weakness of purely voluntary co-operation as a remedy has been illustrated more than once. (The comparative failure of the Scottish Milk Agency scheme may be cited as an instance.) In view of all this, the difficulties and controversies to which the Marketing Acts and their derived schemes have given rise may be a matter for some surprise, but only, I think, to those not familiar with all the facts. One fact is the strong individualism of the British farmer, begotten of tradition, experience, and his whole way of life. Sometimes, in the modern world, individualism may be a handicap; but the modern world too can show us many instances in which its absence is even more to be deplored. In this country most of us still believe that, in the words of John Barbour, 'Freedom is ane noble thing.' We must, however, retain our sense of perspective, and it is possible to exaggerate the degree of subservience to which farmers are subjected by a scheme which a majority of them was free to accept or reject and which, when accepted, is administered by their own representatives. Another and an important fact is that the marketing schemes are of a novel and necessarily complicated kind. Experience has to be gained, experiments have to be made, the engine has to be run in, mistakes in driving, sometimes serious mistakes, are inevitable for a time. Patience and tolerance are required. It is better surely to adjust the bearings and tighten loose nuts than to throw the spanner into the works and wreck the whole machine. For even the critic must admit that the Acts and the schemes are at least earnest attempts to remedy serious defects in one important side of British farming.

The subject is being treated in a separate paper this morning and I do not propose to discuss it in any further detail. But I will conclude my reference to it by quoting the opinion of one authority who has written: 'The Marketing Acts are the equipment for a great experiment in the possibility of farmers organising their industry themselves, with due regard to the interests of the consumers. If the experiment succeeds, it may postpone indefinitely such drastic changes in the structure of agriculture as those which are taking place in Soviet Russia. If it fails, not less but more control will be inevitable.' How many of you will agree with that view I do not know.

Having considered briefly the methods by which the State helps the farmer by laying restrictions on him for his good, and by handing him the keys with which to open, if he will, the palace called Organised Marketing, where the enchanted princess, disguised as the British housewife, awaits him, let us now, in the third place, glance for a moment at the other ways, some of them quite direct, in which he is aided and supported. Fortunately, it has been unnecessary for me to seek out all the facts from the numerous and sometimes rather elusive official publications and records in which they are contained, for that difficult task was most ably performed two years ago by Dr. Venn, to whose address I refer you. At the levels then current, the gross total of financial assistance afforded to agriculture, including forestry, and allowing for local taxation reliefs, amounted to upwards of thirty-three and a half million pounds, from which he deducted
ten and a quarter millions representing the debit caused by the action of the Wages Committees, thus bringing out a net gain of about twenty-three and a half millions. Some adjustment of these figures is required at the present date. Owing to the rise in the price of wheat, the wheat subsidy, which as you know is not a direct Treasury grant but is obtained from the consumers of flour, is at present negligible. On the other hand, the cattle subsidy now stands at five millions instead of three and a third and sums amounting to a maximum annual total of £3,490,000 have lately been promised in respect of oats and barley, lime and basic slag, land drainage and the reduction of live stock diseases. In his balance sheet, Dr. Venn, no doubt wisely, made no allowance for the option afforded to the farmer of being assessed for income tax on his rent instead of on his actual profits, should these prove to be the greater. What that special concession is worth, it is impossible to estimate, but with any improvement in the financial position of the industry its value progressively increases.

The items in the balance sheet, apart from the recent additions which I have mentioned, are, as you may remember, wheat, beet, meat, milk, land settlement and allotments, afforestation, local taxation relief, and administrative and development services. This last is a comprehensive item embracing many and varied matters such as live-stock improvement, land drainage, etc., and including the subjects which are of special interest to many members of this section, Education and Research. For the financial year 1912–13, the State grants for these subjects amounted to £65,750 in England and Wales, and £34,889 in Scotland, a total for Great Britain of £100,639, whereas in 1936 the corresponding figures were £628,570 in England and Wales, and £136,769 in Scotland, a total of £765,339.

These are large and striking increases, but it must be remembered that for many years our standard of expenditure on these services was much lower than that in several other countries, so that if we were to attain, as we have done, fairly adequate recognition of their importance within a reasonable time, a steep financial ascent was inevitable. In view of the interest in the subject, it is tempting to ascertain whether this growing outlay has been reflected in an increased yield of agricultural products. The question, however, is not an easy one to answer, since many factors are at work, and it is difficult to ascribe an increase to any particular one. The output of live-stock products, for example, must depend very largely on the prices of imported feeding stuffs. Possibly the least fallacious measure to apply is the average yield per acre of our principal crops, though here again the problem is not simple. For instance, if the total acreage of a crop falls, the average yield per acre tends to rise, since it is from the least suitable land that the crop will be withdrawn; conversely, an extended acreage will probably mean a somewhat smaller average production. It is subject to this and other qualifications that the following tables should be taken as providing any indication of the effects of our education and research. The figures are for 35 years from 1900 onward and are given as quinquennial averages, so as to smooth out to some extent annual fluctuations due to weather conditions, etc.

In Great Britain as a whole, wheat, the acreage of which has fallen since
the war years, shows no significant increase, oats are up by 4 or 5 bushels and potatoes by something like half a ton, but rotation hay has made no advance in spite of a reduced acreage. The results are not spectacular, but the economic difficulties of many farmers, in the later periods, must be kept in mind. Any variations are, however, in the right direction, and striking changes in averages for the whole country could hardly be expected. A general rise in national production is bound to be a slow movement. But there are doubtless considerable numbers of the more progressive farmers who, by availing themselves of the aid offered by the

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<tr>
<td>1900-04</td>
<td>1,645,774</td>
<td>3,094,642</td>
<td>569,399</td>
<td>2,331,575</td>
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<td>29.83 Bushels</td>
<td>39.24 Bushels</td>
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<td>29.50 Cwt.</td>
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<td>1905-09</td>
<td>1,725,616</td>
<td>3,061,529</td>
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<td></td>
<td>33.28 Bushels</td>
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<td>6.20 Tons</td>
<td>30.23 Cwt.</td>
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<td>1910-14</td>
<td>1,852,994</td>
<td>2,964,502</td>
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<td></td>
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<tr>
<td>1915-19</td>
<td>2,227,592</td>
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<td>650,973</td>
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<tr>
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<td>39.18 Bushels</td>
<td>6.19 Tons</td>
<td>29.10 Cwt.</td>
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<tr>
<td>1920-24</td>
<td>1,879,088</td>
<td>3,107,942</td>
<td>666,289</td>
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<tr>
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<td>31.94 Bushels</td>
<td>38.30 Bushels</td>
<td>6.18 Tons</td>
<td>28.92 Cwt.</td>
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<tr>
<td>1925-29</td>
<td>1,546,255</td>
<td>2,725,711</td>
<td>646,886</td>
<td>2,000,654</td>
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<tr>
<td></td>
<td>32.36 Bushels</td>
<td>43.38 Bushels</td>
<td>6.48 Tons</td>
<td>28.38 Cwt.</td>
</tr>
<tr>
<td>1930-34</td>
<td>1,516,509</td>
<td>2,428,413</td>
<td>614,942</td>
<td>1,884,938</td>
</tr>
<tr>
<td></td>
<td>32.20 Bushels</td>
<td>43.56 Bushels</td>
<td>6.56 Tons</td>
<td>28.58 Cwt.</td>
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</tbody>
</table>

scientist, have obtained increases much in excess of any shown in the table. It has to be remembered, too, that even where yields have not increased, costs of production may have been substantially reduced.

There are some other branches of State intervention which, notwithstanding their importance, it must suffice just to mention: protection of the farmer by means of import tariffs and quotas, designed to raise or maintain the prices of his products; the Agricultural Holdings Acts, controlling the relationship of landlords and tenants; land settlement legislation, which enables new holdings to be established on land which, under certain conditions, may be compulsorily acquired for the purpose.

In the course of an hour's address it is not possible to do more than take
a hasty glance at this large subject, with its many interesting ramifications, any one of which might well have a whole volume to itself. But inadequate as the survey has been, there are one or two deductions that may perhaps be drawn from it.

Comparison of an agricultural country like Denmark with an industrial country such as ours must not be carried too far. Marketing and other organisation, opportunities of alternative employment, standards of living, necessarily differ in the two countries. But allowing for all this, the statistical tables quoted in the earlier part of the paper suggest that British agriculture at present falls short of producing as much home-grown food as is possible and desirable for the nutrition of the people and also of affording employment on the land to as many persons as is reasonably practicable. The need of higher nutritive standards for a number of our population and the importance, in attaining these standards, of larger supplies of certain foods, in the production and marketing of which our farmers have some natural advantages, are now generally recognised. This recognition is tending to encourage the development of certain branches of our agriculture and it is to be hoped that the process will be a progressive one. Some authorities seem to consider that the sole impetus required to accelerate the process is to increase the purchasing power of the lower-paid groups of the population. That is certainly a factor of much importance, but there may be need too for education in the principles of nutrition, not only among these groups, but among some others as well. This aspect of the matter will no doubt be kept in mind should it be thought advisable to devise schemes for securing the desired object.

When speaking of the greater employment of the people on the land, one is apt to be reminded at once, and quite properly, that, thanks to the activities of the scientist and the engineer, the output per unit of agricultural labour is steadily rising. This is a tendency that can be neither ignored nor retarded. Increased production, therefore, may not necessarily cause increased employment. But, on the other hand, it is probably true that it will be long ere, in this country, the large-scale mechanised farm, the ideal of the economist, is the general and normal agricultural unit. And, given reasonable prospects of even moderate commercial success, there are many for whom rural life holds a fascination and independence denied to the townsman and the factory worker. For agriculture, as has been said, notably by Professor W. G. S. Adams, in his paper read to this section at Aberdeen, is not only a living, but a way of life. To live in that way, they are willing to risk the financial vicissitudes of the farmer or even to undertake the arduous labours of the small-holder. Cynics may call it sentiment; it is none the less a fact. But the question is by no means entirely one of settling people in new holdings; at present it is indeed rather one of making up leeway both in land and in the people employed on it. Since before the war, two million acres have gone out of arable cultivation. The reclamation of waste lands in England, the repopulating of our Scottish glens are perhaps less immediately possible, but is it too much to hope that at least a good part of these two million acres might be recovered? Were it solely a matter of farming economics, the shrinkage of our cropping area and extension of our grass-lands
might perhaps be regarded with equanimity, especially if the grass were of reasonably good quality. But wider issues are involved; the effects on employment and food production cannot be left out of account.

In the second place, when one compares the amount of control to which agriculture is subjected by the State and the amount of benefits, direct and indirect, which it receives, one cannot fail to notice some disparity between the two. The State is paying the piper fairly substantial sums, but while it exercises a little restraint over some of his actions, its only method of calling the tune is to offer special rewards for certain specified melodies. Some people may say that the payments should be larger, or different in form or in distribution; others perhaps may think that with so much foreign music available, it does not greatly matter what our piper plays. But at any rate the fact is that the selection of the tunes is ultimately determined only by individual choice. And one can hardly help asking, somewhat anxiously, whether, if the system of payments, in their various forms, is to be continued or extended, the freedom and independence of the piper can be maintained. To drop the metaphor, if it be the policy of the State to preserve and support the farmer, at considerable cost, is he to cultivate and crop his land, to produce meat or milk or other products, as he thinks best, without any dictation as to methods, quantity or quality? I would emphasise that the question is not whether the farmer should be supported and protected, but only whether there is a possibility that, sooner or later, certain consequences may follow from that policy. It is true, as I have said earlier, that it is difficult for a Government to pass and to administer an unwelcome law; but if Government aid were made conditional on Government control, the farmer, however distasteful he found it, might be induced to swallow the pill for the sake of the gilding.

It may be argued that the State, in return for its expenditure, whether in the form of direct payments or of artificially raised prices, is entitled to demand not only certain goods, but a certain standard of performance, a view that found expression in Part IV of the Corn Production Act, which gave 'Power to enforce proper cultivation.' In response to that argument, it may be claimed that if the farmer is to be bound to produce commodities of a kind, quality and amount determined according to the kind and area of his land, he should be insured against any loss incurred in the process. And that leads to the further question: if he is to be insured against loss, is he to be left free to make unlimited profits, should his efforts prove successful? It is easy to follow out this line of thought and to see complete control, including rents as well as wages, following in due course, and, indeed, the ultimate incorporation of every agriculturist in the Civil Service! *Timeo Danaos et dona ferentes!* Possibly this is all merely academic speculation, but given the premise of State support, the subsequent reasoning does not seem to be entirely fallacious. Whether the conclusion, if it were ever reached, would be a desirable one, is a matter for individual opinion.

Thirdly, it may be noted that, while some of the State benefits, e.g. rating relief, the fruits of education and research, etc., are bestowed upon all, certain others, e.g. the wheat and beet subsidies, are, owing to natural conditions, not universally available. This is a thorny subject—although
SECTIONAL ADDRESSES

not quite so prickly as it was a few months ago—about which some of us have heard a good deal in the last year or two. The State is, of course, entitled to pay for those commodities the production of which it wishes to maintain or increase, or to come to the rescue of those whom it deems most needful or deserving of succour. If, for instance, a 'nutrition' policy required an increase of, say, meat, or milk, or fresh vegetables, or if the agriculture of one part of the country were, for some reason, in special jeopardy, the disbursement of funds for such purposes would appear to be perfectly legitimate. But if it were a permanent policy for the State to support British agriculture in general, it might perhaps be desirable to survey the whole industry, its place in the social and economic structure of the country, its present and potential capacity to meet the food requirements of the people, and its relation to international trade. These subjects are no doubt being studied now, but it can hardly be claimed that the study is complete. Perhaps it never can be completed, for many of the factors are far from static. But if a comprehensive, reliable and possibly continuous survey could be made, it might form the basis on which State aid might be allocated equitably, from time to time, to those branches of the industry which it was desired, in the public interest, to encourage and in proportions according to their needs. But on this assumption, the shadow of State control still lurks darkly in the background.

This leads one, lastly, to consider whether in State aid, with its attendant shadow, lies the only hope for British agriculture. The question is one of paramount importance and of formidable difficulty, on which any one should hesitate to dogmatise. But for some at any rate there would be comfort in the belief, if they could hold it, that our farmers, given a fair share of our home markets, could once more struggle through their difficulties and maintain their position by their own initiative, energy and resource. For many of them, times have been hard, but many too are riding out the storm with courage and success. Observation, supported by careful economic investigation, shows that the personal factor is still one of enormous importance. Within one parish, even on neighbouring farms, great disparity in farming practice and results may be found. The man of enterprise and adaptability, the man who is eager to acquire new information, to test new methods in the light of his practical experience, and to apply his mind to the business management of his undertaking, he is the man who is least clamant for State subvention to help him in balancing his accounts. Education and research, both scientific and economic, have yet many gifts in store, gifts the acceptance of which carries no penalties. If they be accepted willingly and applied diligently, is it not possible that the general standard of our farming might be raised to a level at which it would be beyond the reach of any, save the very heaviest, waves of depression? If not, there seems to be at least a risk that our farming, no longer the free industry that we know and respect, may become a mere hanger-on of the State, dependent on its bounty and subject to its commands. Economic independence is worth a struggle, for with it may go a higher kind of freedom that is worth the hardest fight of which man is capable.
REPORTS ON THE STATE OF SCIENCE,
Etc.

SEISMOLOGICAL INVESTIGATIONS.

Forty-second Report of the Committee of Seismological Investigations (Dr. F. J. W. Whipple, Chairman; Mr. J. J. Shaw, C.B.E., Secretary; Miss E. F. Bellamy, Prof. P. G. H. Boswell, O.B.E., F.R.S., Dr. E. C. Bullard, Dr. A. T. J. Dollar, Sir Frank Dyson, K.B.E., F.R.S., Dr. A. E. M. Geddes, O.B.E., Prof. G. R. Goldsborough, F.R.S., Dr. Wilfred Hall, Mr. J. S. Hughes, Dr. H. Jeffreys, F.R.S., Mr. Cosmo Johns, Dr. A. Milne, M.B.E., F.R.S., Prof. H. H. Plaskett, F.R.S., Prof. H. C. Plummer, F.R.S., Prof. J. Proudman, F.R.S., Prof. A. O. Rankine, O.B.E., F.R.S., Rev. C. Rey, S.J., Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, F.R.S., Mr. J. Scrase, Dr. H. Shaw, Sir Frank Smith, K.C.B., C.B.E., Sec.R.S., Dr. R. Stoneley, F.R.S., Mr. E. Tillotson, Sir G. T. Walker, C.S.I., F.R.S.)

Meeting of the Committee.

The Committee met once during the year, on November 27. Dr. E. C. Bullard, Dr. A. E. M. Geddes and Prof. J. Proudman, F.R.S., were co-opted as members. The annual grant of £100 from the Caird Fund and the special grant of £50 from the same fund were allocated to the University Observatory, Oxford, for work on the International Seismological Summary. Prof. Plaskett was able to inform the Committee that increased support for the Summary was being received from the International Union for Geodesy and Geophysics through the Seismological Association, so that the financial position could be regarded as satisfactory.

The Committee considered the possibility of the inauguration of experiments to determine by seismological methods the structure of the Continental shelf near the British Isles. Such experiments have been made with success off the east coast of North America.

The Gray-Milne Fund.

There has been no considerable call on the Gray-Milne Fund during the year. The income of the fund has improved on account of the partial resumption of the payment of dividends by the Canadian Pacific Railway. Purchases for the Milne Library include Vol. I. of the Introduction to Theoretical Seismology by Macelwane and Sohon and Earthquakes by Heck.

Gray-Milne Fund.

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<td><strong>Total</strong></td>
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Operation of Seismographs: £6 8 1
Milne Library: £3 3 0
Insurance: £15 0
Balance June 30, 1937: £187 4 2

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<tr>
<td><strong>Grand Total</strong></td>
<td>197</td>
<td>10</td>
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Seismographs.

The six Milne-Shaw seismographs belonging to the British Association have remained on loan to the seismological stations at Oxford (2), Edinburgh, Perth (W. Australia), and Cape Town (2).

Mr. Shaw reports that the seismograph exhibited in Edinburgh at the meeting of the International Union for Geodesy and Geophysics has been despatched to Brisbane. Another is nearing completion for Durham and a further machine is on order for the Azores.

British Earthquakes.

A slight earthquake which occurred at 1.43 G.M.T. on July 9, 1937, was felt over an area about 30 miles in diameter, centred near Walsall. Records were obtained at West Bromwich, where the disturbance lasted for about 1½ minutes, and also at Stonyhurst, Oxford and Kew. Mr. F. J. Dixon, Engineer-in-Chief to the South Staffordshire Waterworks Company, sent for inspection a pressure diagram on which the movement was well marked. It was a daily chart recording at Walsall the pressure in a 24-in. cast-iron main. At the time of the shock the recording pointer rose from 129 lb. per sq. in. to 136 lb. and fell to 122 lb. Whether this was the result of an actual change of pressure in the pipe, or due to a mechanical vibration of the instrument is uncertain.

On other dates the following small disturbances were reported in the newspapers:

December 29, 1936. East Kent.
April 7, 1937. North Staffordshire.

It may be noted here as an item of information with regard to British earthquakes that in a paper published in *Gerlands Beiträge zur Geophysik*, 48 (1936), 239, Prof. V. Conrad, using material prepared by the late Dr. F. B. Nopcsa, finds that there is no tendency in the British Isles for earthquakes to be associated either with rising or with falling barometric pressure. This is in contrast with the conditions in certain continental countries, notably Italy and Norway, where the regions in which one tendency or the other prevails are well defined.

Seismology in the West Indies.

The report by Dr. C. F. Powell 1 on the seismological part of the work of the Royal Society Expedition to Montserrat has been published as well as Mr. Macgregor's 2 account of the geology of the island.

Dr. Powell was able to locate the epicentres of 43 earthquakes which were registered by the Jaggar shock-recorders made at Kew Observatory for the expedition. It is reported that the seismic activity on the island has continued to diminish, so that the opportunity for investigating the nature of the earth movements has passed. It is hoped that arrangements will be made for the installation of shock-recorders in several of the islands in the Lesser Antilles, so that a watch may be kept on any development of new activity in that region.

In a recently published account of the meteorology of Jamaica attention

has been called by Mr. J. F. Brennan, the Government Meteorologist, to the remarkable character of the minor earthquakes in that island. The following table, showing month by month, (a) the average number of earthquakes, and (b) the average rainfall, has been derived from his statistics. The earthquake observations cover the period 1908 to 1934, the rainfall records a period of 60 years.

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<tbody>
<tr>
<td>Rainfall. In.</td>
<td>2.0</td>
<td>2.3</td>
<td>2.0</td>
<td>1.0</td>
<td>0.9</td>
<td>1.6</td>
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<tr>
<td>July</td>
<td>4.00</td>
<td>3.13</td>
<td>3.35</td>
<td>4.77</td>
<td>8.77</td>
<td>6.53</td>
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The following table, showing month by month, (a) the average number of earthquakes, and (b) the average rainfall, has been derived from his statistics. The earthquake observations cover the period 1908 to 1934, the rainfall records a period of 60 years.

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<tbody>
<tr>
<td>Rainfall. In.</td>
<td>4.75</td>
<td>6.93</td>
<td>7.94</td>
<td>10.21</td>
<td>8.29</td>
<td>5.20</td>
<td>73.87</td>
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</table>

It will be seen that the earthquakes are most frequent in the dry months of the year. Brennan's explanation is that the shocks are due to rockfalls in the underground watercourses, the geological formation of three-quarters of the island being limestone. These minor earthquakes have been growing less numerous in recent years as the great earthquake of 1907 has become more distant. In view of an apparent association with that catastrophe it is clear that closer study of the minor earthquakes is desirable.

**Work at the University Observatory, Oxford.**

Since the last report, the sections of the International Seismological Summary for the quarters ending 1931 September and December, also 1932 March, have been completed and distributed. April and May are printed, and the MS. for June, July, August and September are ready for press. The Summary for the whole year 1931 was sent as a bound volume to recipients preferring that form to separate quarterly sections.

A set of 'Tables for the near Earthquake Pulses,' completed by Dr. Jeffreys, to supplement the Jeffreys-Bullen Tables which are the basis of the Summary and are to be found in the 1930 volume, has been printed and distributed as a pamphlet.

A new list of 'Constants of Seismological Observatories' has been prepared and will be issued shortly. This includes 116 new stations to be added to the list published by K. E. Bullen in 1933. A geographical index has been added at the end.

An Index Catalogue of Epicentres for 1913–1930, prepared by Miss E. F. Bellamy, was issued in the autumn of 1936. This catalogue incorporates and extends to 1930 the list published by Prof. H. H. Turner in 1920. All the epicentres given in subsequent volumes of the International Seismological Summary are included. The catalogue is divided into four parts, the first part containing epicentres north of the equator and east of Greenwich, and the other parts including the N.W., S.E. and S.W. quadrants of the globe. In each part the epicentres are listed with all those in the same latitude together. The total number of shocks for which epicentres were determined in the 18 years was 6,738. Of these 4,007 were in the N.E. quadrant, 1,106 in the N.W., 957 in the S.E. and 668 in the S.W. There were 38 in the far north in latitudes as high as 70° N. but only 3 between 70° S. and the South Pole. The positions of the epicentres are shown on a chart on the Mollweide Equal Area Projection and the positions of seismological stations are shown on a similar chart. The Index Catalogue should
be used in conjunction with the Catalogues of Earthquakes arranged in order of date; the last of these, covering the years 1925–1930, was also prepared by Miss Bellamy and was published in the B.A. Report in 1935. The Committee wishes to congratulate Miss Bellamy on the completion of a catalogue which will be gratefully appreciated by all seismologists.

The New Globe.

The new globe for use in determining epicentres at Oxford has been in service since October, 1936, and is a great success. This instrument was made by Casella, London, and is of brass with an electroplated surface which will take either an ink or pencil line extremely well, and yet can be cleaned easily. The globe is set on a wooden stand which supports a bed of baize, so that by rotation any point of it may be made the highest. A detachable arm can be screwed to the side of the stand, and bears a pointer and moveable celluloid scale which rotates at will and measures distances and azimuths of any points on the surface relative to an origin which is the highest point of the globe and immediately beneath the pointer. The azimuth scale is fixed to the wooden stand and is graduated from 0° to 360° in both clockwise and counter-clockwise directions, so that in dealing with earthquakes either the epicentre or anti-centre may be used as origin.

There are also compasses graduated from 0° to 120° for drawing arcs of circles on the globe; these bear a point at one end for insertion into a small hole whose position corresponds with that of an observing station and a 'stylo' type of pen at the other; this latter caused considerable trouble at first as the tube of the pen was continually being blocked with dried ink, but this difficulty has now been overcome. There is also an alternative fitting bearing a lead pencil.

The exact size of the globe is such that 10° of arc equals 4 cms., so that roughly the diameter is 18 in. The weight is about a half hundredweight and constitutes a handicap when it is necessary to turn the globe round by hand, although with practice it soon becomes comparatively easy to set to any part of the surface with ample accuracy. The surface has been ruled in 10° intervals of both latitude and longitude as far as 80° north and south of the equator and the accuracy of the ruling is great, so that were it not for a systematic error in the flexible scale distances could be read off exactly. As it is, the scale is in error by 1 per cent. or thereabouts and this must be allowed for, a point which hardly detracts from the utility of the instrument.

Small holes in the surface have been drilled in positions corresponding to the principal observing stations and an abbreviated name engraved against each; this was done before the electroplating, so that the surfacing was not marred by the engraving.

The International Seismological Summary, 1932—Some Notable Earthquakes.

By J. S. Hughes.

In the report for 1936 attention was drawn to a shock on 1931 August 10, from an epicentre in Western Mongolia, whose observational data possessed considerable abnormality, and I pointed out that their effect was to give a divergence from the normal, similar in extent but opposite in sign to that of a depth of focus 0·030. Subsequently a further independent investigation by Dr. Stoneley made it extremely probable that the data referred to two shocks having the same origin but separated by an interval in time of
about 25 secs. Recently a further case of 'high focus' has been noticed. The earthquake of 1932 September, 26th, 19h, 20m, 42s., with epicentre 39°·8 N., 23°·8 E., in N.W. Aegean Sea, just outside the Gulf of Salonica, is very well recorded over a range of distances from 5° (Italian stations) to 158° (New Zealand stations), and 120 P readings are in approximate agreement. However, a consistent difference exists in residuals between the European group of stations and the North American, both in the same azimuth, and the only explanation that seems to fit the circumstances is that the European stations are at the distance at which travel times are not much affected by focal depth (or height) whereas at the distances of the American stations about the observed amount of delay would be expected. On the Turner scale of $\Delta$ corrections for abnormal focus a 'height' of 0·0075 has been applied; this brings into line the otherwise discordant times at different distances in the same azimuth.

There were numerous deep focus earthquakes in 1932. The large Japanese earthquake of April 4th from epicentre 30°·6 N., 139°·5 E. off the coast, is a useful illustration of the good fit of the Turner deep focus correction tables. It is not necessary to claim that the fraction used to define the depth must be exact as a proportion of the earth's radius, but it does constitute a relative standard by which depths of focus in different earthquakes may be compared. In the present case the depth is nominally 0·065 of the earth's radius or 400 km., and the Turner corrections account for the differences of observed $\Delta$ from $\Delta = 2^\circ·5$ where the figure is $+1^\circ·8$ to nearly 90° where it is $-8^\circ·0$.

Another important Japanese deep focus earthquake occurred on 1932 November 13th at about 43°·6 N., 137°·3 E., with focal depth about 0·050. The details of this are not yet finally settled, but it is one of the most widely recorded shocks and will furnish data from stations at all distances.

The Mongolian Earthquake of 1931, August 10.

By Dr. R. Stoneley.

In last year's B.A. Report Mr. Hughes commented on a peculiar feature of this earthquake; the P observations determine the epicentre as 46°·9 N., 96°·0 E., accurate within 0·1, but the S readings are then about 30 sec. late. According to the old I.S.S. routine this would probably have indicated a 'high focus' shock.

One possible explanation immediately suggests itself. In the absence of microseisms, P can be picked out without difficulty, even if of very small amplitude, whereas S has to be read against an already disturbed 'background.' It is fortunate for seismology that S is generally of relatively larger amplitude than P. If a rather weak shock is followed a few seconds later by a decidedly stronger shock, distant stations will tend to read the P of the first shock and the S of the second. This explanation seems to apply to the earthquake under consideration.

By the kindness of Mr. Hughes and Miss Bellamy I have been able to examine the seismograms of Oxford and Dyce and to make use of a preliminary proof of the I.S.S. In both records the earthquake begins as an eP, followed 3 or 4 sec. later by an iP. The calculated time falls between the eP and the iP. There is a very clear sudden onset for which O–C is about 33 sec. for Oxford and 32 sec. for Dyce; these onsets cannot be explained as reflected waves. The Kew records, for the loan of which I am indebted to Dr. Whipple, are quite convincing; the prominent onset some
30 sec. after P is listed provisionally in the Kew Bulletin as PcP, and is obvious on all three components. The records indicate another P between these two, but it is less sharply defined; I read this intermediate onset on the Oxford and Dyce records as 10 and 15 sec. after the calculated times of P, and the Kew Bulletin lists it at 15 sec. Only one station seems to have suspected a multiple shock: Upsala interprets the readings as indicating two aftershocks 20 and 33 sec. after the calculated time of the first shock, and identifies the corresponding PP, S, etc. It is rather difficult to pick out S on the seismograms, and to avoid personal bias it is better to examine the station readings.

All the P readings in the I.S.S., including the ‘Additional Readings,’ were analysed. The additional readings gave the following distribution for residuals for P, from 9 to 42 sec.: 8 residuals above this were sparsely scattered and could be ignored.

\[
\begin{array}{cccccccccccccccccccc}
0 & 2 & 3 & 3 & 2 & 0 & 3 & 0 & 0 & 0 & 2 & 3 & 3 & 0 & 3 & 0 & 1 \\
26 & 27 & 28 & 29 & 30 & 31 & 32 & 33 & 34 & 35 & 36 & 37 & 38 & 39 & 40 & 41 & 42 \\
2 & 0 & 2 & 4 & 1 & 2 & 1 & 7 & 6 & 2 & 2 & 0 & 2 & 1 & 1 & 1 & 1
\end{array}
\]

The concentration of residuals about 33–34 sec. is unmistakable, especially if, as a rough method of clearing out random large errors (Jeffreys, Geophysical Supplement, 2, 335), we make a uniform deduction of one per group. There is rather slight evidence of onsets at about 12 and 21 sec. after the calculated P. A corresponding analysis of all readings available for S gave:

\[-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 \\
1 2 1 2 1 1 0 3 1 2 2 1 4 1 7 5 3 5 1 5 2 \\
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 \\
4 0 1 7 4 9 5 3 8 0 5 3 1 2 5 3 3 5 2 4 4 1 \\
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 \\
1 3 1 1 1 2 1 1 0 1 0 0 1 1\]

These S residuals show decided concentrations round about 10 sec., 19–20 sec. and 31 sec. For the first shock S seems to have escaped notice. Taken all together, the evidence leaves no doubt that the shock is double, and it is possibly treble or quadruple. Ideally, of course, a complete correspondence should be observable among the onsets corresponding to each phase; actually, the phases other than P are not so immediately obvious in the seismograms examined, and there is always the risk of finding just those things that one expects to find.

A check on the accuracy of the I.S.S. epicentre was made by taking the residuals in three well-defined azimuth groups, the Japanese, European and North American stations, and applying the correction for ellipticity recently found by Bullen; the shift indicated is less than one-tenth of a degree, and is barely significant.

It is worth noticing that the S residuals of the shock of 1931 August 18th, 14h., from the same epicentre are not abnormal, but form a rather ‘flat’ distribution round about −1, in which the only anomaly is a group of 12 residuals + 5, where the general run would indicate about 4 such residuals; it is very doubtful if any significance should be attached to this isolated group.
Seismic Transmission Times.

By Dr. Harold Jeffreys, F.R.S.

The most important contribution of the year to theoretical seismology is probably Bullen's determination of the systematic errors due to the neglect of the ellipticity of the earth. The total effect on the arrival time of P at large distances may vary with azimuth by about 5 secs. I have now applied the corrections to the data used by Bullen and myself in the paper we submitted to the Conference at Lisbon in 1933 and to more recent earthquakes suitable for determining the times of S and SKS. Times of P, S and SKS (to 115°) adapted to a spherical earth are now available. Some systematic errors were detected in the process. The maximum departure of the P times from those of Gutenberg and Richter is about 2 secs. The correction introduces a systematic correction into the epicentres, which is small (usually under \( \theta^\circ \cdot 05 \)) for earthquakes in the northern hemisphere, but may reach \( \theta^\circ \cdot 5 \) for southern epicentres if near stations are few or receive insufficient weight: 27 southern epicentres have been redetermined, as a preliminary to a new study of the core waves. It appears that errors in the epicentres may account for the low reliabilities previously found for some of the southern stations. The negative residuals at large distances, noticed by Bullen and me in some southern earthquakes, disappear when the ellipticity is taken into account, and there is no longer any need to suppose that Pacific earthquakes habitually have a small but appreciable focal depth. A preliminary classification of the P residuals by distance suggests that the time to 50° is about 1 \( \cdot \) 5 sec. shorter in Pacific than in continental earthquakes, but further examination will be needed before it can be said that this is not due to a small systematic error of observation. A difference between oceanic and continental travel times might be expected on thermal grounds; indeed, it is rather surprising that the difference should be so small, corresponding to about 1 part in 300.

The seismological evidence indicates rapid changes with depth in the velocities of P and S, possibly a discontinuity, at a depth of about 470 km. Bullen, using the theory of the figure of the earth, finds that the mean density down to the core is too high to agree with that of olivine in its normal state and at the actual pressures. I referred in last year's report to Bernal's suggestion that at high pressure the usual rhombic form of olivine may be replaced by a cubic one of higher density. This hypothesis has been tested by comparison with conditions in the moon. The relevant pressure is not reached in the moon, and the density of the moon is nearly that of surface olivine. Thus the density would agree with Bernal's hypothesis. It would not agree, however, with the presence of a large amount of a different material denser at normal pressures. The former hypothesis being therefore adopted, the moon can be shown to be nearly homogeneous. This provides the additional equation needed to determine the earth's ellipticity from the moon's perturbations, and gives \( \rho/e = 297.2 \pm 0.5 \), the accuracy of which is comparable with that of the determinations from gravity, and has the advantage that the doubtful effect of higher harmonics in the earth's gravitational field does not arise. Dr. H. S. Jones, using slightly different data, gets 296.08 \( \pm 0.95 \). Prof. E. W. Brown and his collaborators are likely to improve these values soon, as the method appears promising.

Reappointment of the Committee.

The Committee asks to be reappointed and for the renewal of the grant of £100 from the Caird Fund.
MATHEMATICAL TABLES.

Report of Committee on Calculation of Mathematical Tables (Prof. E. H. Neville, Chairman; Prof. A. Lodge, Vice-Chairman; Dr. J. Wishart, Secretary; Dr. J. R. Airley, Dr. W. G. Bickley, Prof. R. A. Fisher, F.R.S., Dr. J. Henderson, Dr. E. L. Ince, Dr. J. O. Irwin, Dr. J. C. P. Miller, Mr. F. Robbins, Mr. D. H. Sadler, Mr. W. L. Stevens, Dr. A. J. Thompson and Dr. J. F. Tocher).

General activity.—Seven meetings of the Committee have been held, in London.

The grant of £150 has been expended as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wages and insurance for computer for six months</td>
<td>76</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Purchase of calculating machine</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Checking calculations for Vol. VI (balance)</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Calculations for Bessel functions of order greater than 1</td>
<td>18</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Secretarial and miscellaneous expenses</td>
<td>9</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>

Resignation of Dr. Comrie.—At the outset of the year’s work the Committee received with deep regret the resignation of Dr. Comrie, who had entered business as a professional computer. The Committee desires on this occasion to place on record its appreciation of the services Dr. Comrie has rendered during the past eight years, and in particular of the work he has done as secretary. The successful translation of the activity of the Committee into published volumes owes a great deal to his enthusiasm and efficiency.

Employment of Computers.—The resignation of Dr. Comrie raised the questions of the location of the Association’s National Accounting Machine, which had been housed for some years at H.M. Nautical Almanac Office, and of the provision which should be made for regular work with the machine. Prof. Fisher offered to house the machine in the computing room of the Galton Laboratory, and this offer was gratefully accepted, W. L. Stevens, who is in charge of the computing room, being added to the Committee. It was considered that the best way of arranging for the calculations to be carried out was to employ a whole-time computer, who would work in the Galton Laboratory, and F. Cleaver was appointed to this post in January. The arrangement has worked very well, and it is considered a great advantage that members of the Committee who undertake to be responsible for particular tables should be able to call at will on the services of a computer who is familiar with the National machine.

Several part-time computers have been engaged under the direction of members of the Committee on work for which machines less elaborate than the National were suitable, and in this connection it is a pleasure to acknowledge the readiness with which permission was granted for computers to use the equipment of the Mathematical Laboratory of the University of Liverpool.

The Committee has purchased an additional calculating machine, of the Triplex-Brünsviga type.

Bessel Functions.—The tabular matter of the Committee’s sixth volume, which is the first volume of Bessel functions and contains the four principal functions of orders 0 and 1, is now in the press; the printed sheets are being
checked before the volume is published, and it is expected that the volume will appear before the end of 1937.

Work on the preparation of a second volume, to contain functions of higher integral order (up to \( n = 20 \)) has continued. The calculation of values of \( I_n(x) \) for \( n = 2(1)22 \) and \( x = 0.1(0.1)6.0 \) has been completed under the supervision of Dr. Thompson, and of values of \( K_n(x) \) for \( n = 2(1)20 \) and \( x = 0.1(0.1)6.5 \) under the supervision of Dr. Bickley. Further work has been carried out on the calculation of \( k_n(x) \), i.e. \( x^n K_n(x) \), up to \( x = 6 \) at interval \( 0.1 \) for \( n = 0(1)20 \).

Table of Powers.—Most of the powers required, in addition to those given in Glaisher’s table (see 1936 Report), have now been completed. Considerable progress has also been made towards checking the whole, and in the preparation of copy, mainly on the National machine. Valuable assistance in the computation has been given by Miss E. J. Ternouth and Mr. C. E. Gwyther.

Airy Integral.—During the last year the scope of the proposed table (see 1936 Report) has been much enlarged. The computation of pivotal values over the extended range has now been completed, and the methods of subtabulation and preparation of copy are under consideration.

Sheppard Tables.—Council authority is being sought for the separate publication of certain tables related to the probability integral of the normal curve, which were handed to the Committee by the family of the late Dr. W. F. Sheppard. One table of the ratio of tail area to ordinate of the normal curve, to 12 places of decimals at interval \( 0.01 \), together with reduced derivatives, was left incomplete by Dr. Sheppard, and the Committee has completed the calculations.

Legendre Functions.—Authority has been obtained from Council for the separate publication as a part-volume of these tables (see 1936 Report). The tables are in the press, and will appear as the first of the series of part-volumes which the Committee proposes to issue.

Reappointment.—The Committee desires reappointment, with a grant of £200. A whole-time computer could be employed throughout the year on calculations of Bessel functions and the Airy integral.

THERMAL CONDUCTIVITIES OF ROCKS

Report of Committee appointed to investigate the direct determination of the Thermal Conductivities of Rocks in mines or borings where the temperature gradient has been, or is likely to be, measured (Dr. Ezer Griffiths, F.R.S., Chairman; Dr. D. W. Phillips, Secretary; Dr. E. C. Bullard, Dr. H. Jeffreys, F.R.S., from Section A; Dr. E. M. Anderson, Prof. W. G. Farnsides, F.R.S., Prof. G. Hickling, F.R.S., Prof. A. Holmes, Dr. J. H. J. Poole, from Section C).

It has appeared that the disturbance of the measured temperature gradient in irregular country is likely to be appreciable, since the outer surface is constrained to be at atmospheric temperature, and the mean decrease of temperature with height in the air is about a fifth of that in the crust. A formula for the appropriate allowance has been found by Dr. Jeffreys; the theory is an application of the potential theory of Green.

It has been found that temperatures in a borehole can, with suitable
precautions, be measured with considerable accuracy, using thermo-
junctions. It is possible to measure the temperature gradient to a few
per cent. in a hole 100 ft. deep. The conductivity can be determined by
burying heaters in the hole and noting the temperature distribution round
them. Two values may be obtained, one from the final temperature
distribution and one from the rate of rise and the specific heat. In pre-
liminary experiments in a 15-ft. hole the method was found to work well;
no attempt was made to get the highest accuracy, but the values obtained
by the two methods at different distances above and below the heater agreed
to 3 per cent., which is within the experimental error. The boring of a
100-ft. hole has been postponed till after Dr. Bullard’s return from America
in September.
The cost of boring the hole is estimated at about £40, and the Committee
asks for reappointment with a grant of that amount.

PHOTOGRAPHS OF GEOLOGICAL INTEREST.

Twenty-eighth Report of the Committee (Prof. E. J. Garwood, F.R.S.,
Chairman; Prof. S. H. Reynolds, Secretary; Mr. H. Ashley,
Mr. G. Macdonald Davies, Mr. J. F. Jackson, Dr. A. G. Mac-
gregor, Dr. F. J. North, Dr. A. Raistrick, Mr. J. Ranson, Prof.
W. W. Watts, F.R.S.)

At the Norwich meeting in 1935, at which the 27th report was presented,
Mr. H. Ashley and Drs. A. G. Macgregor, F. J. North and A. Raistrick
were added to the Committee. During the past year the Committee has
lost one of its oldest and most valued members, Mr. R. J. Welch, whose
photographs for uniform excellence, technical and scientific, have probably
never been excelled. Mr. Welch contributed 287 photographs to the Com-
mittee’s collection and 10 of these were reproduced in the series published
by Prof. Watts. Mr. Welch’s contributions to the collection were practically
all pre-war, the earliest being included in the Committee’s first report
(Leeds 1890). In 1897 he sent as many as 93. All his photographs were
whole-plate platinotypes.

In the present report 154 photographs are listed, bringing the number in
the collection to 8,865. The series includes a fine set by a new member of
the Committee, Mr. H. Ashley; Norfolk is the county best represented
in this set, but there are others from Lincoln and Nottingham. Mr. A. G.
Stenhouse sends an excellent series from Fife, Orkney, Shetland and the
Isle of Eigg. The Hon. Secretary contributes photographs from the North
of Scotland and the Bristol and Belfast districts. Mr. G. Macdonald Davies
sends a series from Dorset and Mr. D. E. Owen from Cornwall.

ENGLAND.

CORNWALL.—Photographed by D. E. Owen, B.Sc., Geological Dept.,
Public Museums, Liverpool 3. P.C.

8712. 1 Duckpool, 4 m. N. of Bude. Rugged weathering of hard band
in Upper Culm. 1933.
8714. 3 Boscastle harbour. Blowhole. 1934.
8715. 4 Efford Cliff 1 m. E. of Bude. Recumbent fold in Bude Sandstone. 1933.
8716. 5 Efford Beacon ½ m. S. of Bude. Syncline in Bude Sandstone. 1933.

DORSET.—Photographed by G. Macdonald Davies, M.Sc., 63 Beechwood Road, Sanderstead, Surrey. ½.

8717. 33·1 Durlston Bay and Swanage Bay, looking N. 1933.
8718 33·6 Durlston Bay. Chert bed in Mid. Purbeck. 1933.
8719 33·9 Chalk cliffs between Ballard Point and the Foreland. 1933.
8720 33·10 The Foreland and Old Harry. Chalk sea-stacks. 1933.
8721 33·21 Near boathouse W. of Kimmeridge Bay. Fault in Kimmeridge Clay. 1933.
8722 33·22 Hobarrow Bay. Fault in Kimmeridge Clay. 1933.
8723 33·17 Durdle Door. Vertical Portland Stone. 1933.
8724 34·2 Shore E. of St. Gabriel’s Water, near Seatown. Lias succession. 1934.
8726 34·1 Near Ridgewater, Seatown. Fault in Belemnite Marl (L. Lias). 1931.
8728 32·17 Wear Cliff below Golden Cap. Mid. Lias section. 1932.


8729 31·125 Marsden. Near view of breccia gash in Mid. Magnesian Lst.
8730 31·80 Plawsworth 3 m. N. of Durham. Sand pit in glacial delta Gravels.
8731 31·79 Ferryhill Gorge. Overflow channel of glacial lake of Wear Valley.

GLOUCESTERSHIRE.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. ¼ and ½.

8734 35·4 Avon Section. Black Rock Qu. to Great Qu. ¾—S1. ½. 1935.
8735 35·5 Avon Section. Great or Tennis Court Qu. S1—D1. ½. 1935.
8736 35·6 Avon Section. Great Qu. to Bridge Valley Road. S1—D2. ½. 1935.
8737 35·9 Avon Section. Overthrusts of Observatory Hill. ½. 1935.
8738 30·53 Avon Gorge seen from Suspension Bridge. ¼. 1930.
Observatory Hill and Avon Gorge. Shows the minor thrusts in relation to the big overthrust. 1. 1930.

Avon Section Great Qu. Seminula-pisolite. 1. 1935.

Avon Section Great Qu. Seminula-pisolite. 1. 1935.

Avon Section, right bank D1. Rubbly beds. 1. 1935.

Avon Section, right bank D1. Rubbly beds. 1. 1935.

Avon Section, right Pseudobreccia. 1. 1935.

Avon Section, right Rubbly beds. J. 1935.

Avon Section, right Rubbly beds. J. 1935.

Avon Section, right Pseudobreccia. 5. 1935.

Avon Section. Pond in the Gully Quarry.


Ancaster, on Sleaford Road. Disturbed Lincolnshire Lst. 1936.


S. Holland Drain between Holbeach St. John’s and Sutton St. Edmund’s. Scenery in marshland of S. Lincoln. 1934.

Scottlethorpe, near Bourne. Pisolitic Limestone overlain by surface soil. 1933.

Freiston shore, near Boston. Creek in Alluvium. 1933.

Near Wilsford, on Sleaford-Grantham Road. Infilling in Jurassic Lst. 1935.


PHOTOGRAPHS OF GEOLOGICAL INTEREST

8760 167 E. Runton.
Section of part of Chalk erratic and associated Pliocene beds. 1934.
8761 139 Between E. and W. Runton.
Lower part of great Chalk erratic resting on Till. 1934.
8762 140 Between E. and W. Runton.
Contorted band in Cromer Till 1934.
8763 252 W. Runton.
Thrust plane in drift. 1935.
8764 35 W. Runton.
Paramoudra. 1932.
8765 43 Trimingham.
Mud-flow. 1932.
8766 91 Trimingham.
Erosion of glacial beds. 1933.
8767 261 Weybourne.
Section contorted drift, Weybourne Crag, Chalk. 1935.
8768 324 Paston, 1 m. N. of Bacton.
Cliffs of Cromer Till. 1936.
8769 26 Ostend, near Happisburgh.
Ripple Marks in Cromer Till. 1932.
8770 27 Ostend, near Happisburgh.
Pocket of mud with shell fragments in Cromer Till. 1932.
8771 84 Ostend, near Happisburgh.
Erosion of glacial beds. 1933.
8772 25 Ostend, near Happisburgh.
Laminated Clays in Cromer Till. 1932.
8773 204 Alderford.
Chalk pit with infilling and other features. 1934.
8774 142 Little Walsingham.
Nodules of limonite in Chalk. 1934.
8775 292 Between E. Harling and N. Lopham.
Pipe in Chalk. 1936.
8776 297 Between E. Harling and N. Lopham.
Weathered surface of Chalk. 1936.
8777 222 \(\frac{1}{2}\) m. N. of Holt.
'Cannon-shot gravel.' 1935.
8778 232 1\(\frac{1}{2}\) miles E. of N. Creake.
Section of chalky Neocomian Boulder Clay. 1935.
8779 9 Snettisham.
Section of Carstone. 1932.
8780 375 Thornham, near Hunstanton.
Section of submerged forest. 1936.
8781 151 Hunstanton.
Erosion along joints in Carstone. 1934.
8782 216 Blackborough, near Middleton.
Section of glacial Gravel. 1935.
8783 201 Massingham Heath.
Glacial gravel with angular flints. 1934.
8784 269 Thorpe, Norwich.
Shelly patch in Norwich Crag. 1935.
8785 284 Town Hall, Norwich.
Section, Norwich Crag, 'stone bed' Chalk. 1935.
8786 144 Morston.
Raised Beach. 1934.

NORTHUMBERLAND.—Photographed by S. H. REYNOLDS, M.A., Sc.D.,
The University, Bristol. 4.

8787 31.77 Bamborough Castle.
Current-bedded Coal Measure Sandstone. 1931.
REPORTS ON THE STATE OF SCIENCE, ETC.

NOTTINGHAMSHIRE.—Photographed by HALLAM ASHLEY, The Craigs, Ashtree Road, Costessey, Norwich. P.C.

8788 407 Hawton, near Newark.

8789 408 Beacon Hill, Newark.

8790 409 Beacon Hill, Newark.

8791 410 Beacon Hill, Newark.

8792 411 Beacon Hill, Newark.

Large masses of gypsum in Keuper Marls. 1937.

Keuper Marl with layers of gypsum. 1937.

Cavities in Keuper Marl due to removal of gypsum in solution. 1937.

Keuper Marl with layers of gypsum. 1937.

Gypsum in Keuper Marl. 1937.

SCOTLAND.


8793 36·49 Scrabster.

8794 36·52 Holborn Head, Thurso.

8795 36·53 Holborn Head, Thurso.

8796 36·54 Holborn Head, Thurso.

8797 36·55 Holborn Head, Thurso.

8798 36·58 Holborn Head, Thurso.

8799 36·59 Holborn Head, Thurso.

Boulder Clay on O.R.S.

The Clett.

Coast erosion.

Goe leading to blowhole.

General view of blowholes.

Blowhole.

The 'Deil's Brig' over goe leading to blowhole.

Dipping O.R. flags.

'Greystones,' a storm beach.

Goe.

Gerston stack.

A sea-stack, the 'Brough.'

Goe just S. of the 'Brough.'

Coast erosion.

Nodular bed in O.R.S.

FIFE.—Photographed by A. G. STENHOUSE, Whitelee, 191 Newhaven Road, Edinburgh 6. ⅓.

8808 Inchcolm, Firth of Forth, W. end.

8809 Inchcolm, Firth of Forth, E. end.

8810 Inchcolm, Firth of Forth, N. side.

8811 Elie, Firth of Forth.

Junction of picrite (left) with quartz-dolerite (right). 1906.

Picrite and associated rocks. 1906.

Picrite veined by related rocks of slightly more acid type. 1906.

Raised beach platforms.

INVERNESS.—Photographed by A. G. STENHOUSE, Whitelee, 191 Newhaven Road, Edinburgh 6. 5 × 4.

8812 Sgurr of Eigg.

8813 Sgurr of Eigg, E. end.

8814 Sgurr of Eigg, S. side, towards W. end.

8815 Sgurr of Eigg.

General view from S.E.

Pitchstone with underlying basalt and dolerite.

Pale felsite or porphyry injections cutting pitchstone.

Log of wood in breccia below pitchstone.

All photographed between 1905 and 1910.
PHOTOGRAPHS OF GEOLOGICAL INTEREST

Sutherland.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 4.

8816 34.38 Helmsdale, Kimmeridgian Boulder bed. 1934.

Orkney.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 4. 1936.

8817 36.9 Yescanabie Castle, Stromness. Sea stack.
8818 36.11 W. of Yescanabie Castle, Stromness. Coast of seaward-dipping flags.
8819 36.13 Deerness. Goe leading to the 'Loup' of Deerness.
8820 36.14 Whitaloo Point. The 'Long Goe.'
8821 36.17 Hoy. The 'Old Man' from the sea.
8822 36.18 Hoy. The 'Old Man' from the cliff.
8823 36.22 N. of Finstown. Contorted strata.
8824 36.25 Whitaloo Point. Contorted O.R.S.
8825 36.27 Birsay. Dyke.
8826 37.11 Cliffs of S.W. Hoy from the sea. Shows the 'Old Man.'

Photographed by A. G. Stenhouse, Whitelee, 191 Newhaven Road, Edinburgh 6. 6 x 4.

8827 C. 6 Whitaloo Point. Contorted O.R.S. 1936.

Shetland.—Photographed by A. G. Stenhouse, Whitelee, 191 Newhaven Road, Edinburgh 6. 6 x 4 enlarget. 1936.

8828 D. 4 Cliffs at Eshaness. Spheroidal mass in O.R. larva.
8829 D. 5 Eshaness. Block of injection breccia. 'Ayre.'
8830 D. 7 Eshaness. Contorted calcareous schist.
8831 E. 3 The Alter, West Burra. Contorted calcareous schist.
8832 E. 4 The Alter, West Burra. Natural arch.
8833 F. 1 West Burra coast. Storm beach.
8834 F. 2 West of Hamna Voe.


8835 36.29 Eshaness. Coast of O.R. volcanic rocks.
8838 36.32 Eshaness. Coast of O.R. volcanic rocks.
8839 36.34 Exnaboe. Seaward dip of O.R.S.
8841 36.39 West Burra. Contorted calcareous schist.
8842 36.40 West Burra. Contorted calcareous schist.
8843 36.43 Noss. O.R.S. cliff.
8844 36.42 West Burra. Storm beach.
8845 36.44 Bressay. Breccia.
8846 36.48 South Havra. Contorted limestone.

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<td>Fair Head,</td>
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<td>Sun-cracks in nearly dry bed of the lough.</td>
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<td>Basalt faulted against Chalk.</td>
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<td>Cave Hill, Belfast.</td>
<td>Basalt on Chalk.</td>
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<td>8862</td>
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<td>Slieve Gullion.</td>
<td>The central hills.</td>
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<td>8863</td>
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<td>Hills forming S.W. part of the ring dyke.</td>
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<td>8864</td>
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<td>Slieve Gullion.</td>
<td>Agglomerate with felsite forming 'matrix.'</td>
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TEACHING OF GEOLOGY IN SCHOOLS

Second Report of the Committee appointed to consider and report on questions affecting the teaching of Geology in schools (Prof. W. W. Watts, F.R.S., Chairman; Prof. A. E. Trueman, Secretary; Prof. P. G. H. Boswell, O.B.E., F.R.S., Mr. C. P. Chatwin, Prof. A. H. Cox, Miss E. Dix, Miss Gaynor Evans, Prof. W. G. Fearnside, F.R.S., Prof. A. Gilligan, Prof. G. Hickling, F.R.S., Prof. D. E. Innes, Prof. A. G. Ogilvie, Prof. W. J. Pugh, Mr. J. A. Steers, Prof. H. H. Swinnerton, Dr. A. K. Wells).

In 1936 a Committee of Section C of the British Association presented a brief Report dealing with the claims of Geology for inclusion in the curricula of schools of all types, drawing attention to both the cultural and the utilitarian aspects of the subject. The publication of that Report has recently led to the suggestion from several members of the Association who are more directly concerned with educational problems that a somewhat more extended Report giving details as to the nature of the suggested school courses was desirable.

It is not proposed to recapitulate here the claims, which were advanced in the first Report referred to, on behalf of the introduction of the subject into schools, or to discuss further those changes in the schools examination system and in University entrance requirements which have led to the unfortunate reactions upon the progress of Geology and the supply of students to carry out geological work.

It may be emphasised that science teaching in many schools has long been confined to the subjects of Mathematics, Physics and Chemistry, to which Biology has in some cases been added. In many schools teaching has been confined to one of these sciences, and not infrequently even to one branch of a science, such as Magnetism and Electricity, or Heat and Light. This situation has been met recently by proposals for the development of science teaching on a broader basis: the reasons for this new attitude to science teaching need not be stated here, for they have been clearly set forth in several reports (notably a recent report of the Science Masters’ Association). At the same time other proposals are being made for the alteration of the nature of some School Certificate examinations, especially in relation to University entrance requirements.

It is hoped that while these changes in science teaching are being discussed, consideration will be given to the possibility of introducing some Geology as an alternative or optional subject among the other sciences in school courses, for it is a peculiarly suitable subject for certain schools. There are schools, for example, situated in areas which may be described as natural geological laboratories, where the teaching of Geology would afford an obvious link with the surroundings. Again in schools such as those situated in mining areas, for example, there are equally good reasons for dealing with geological matters; not only is it fitting that pupils should know something of the geological basis of local industry, but since a proportion of the pupils will presumably be concerned with mining problems in later life, an introduction to geological principles will be of considerable utility.

It is not only in such areas, however, that Geology could effectively be
taught, for it would find an appropriate place in urban schools also, especially where museums make special provisions for the display and supply of teaching materials. London schools are particularly fortunate in the facilities thus afforded; for instance, the models, photographs, dioramas and other exhibits at the new Geological Museum are of such outstanding value that it may be claimed that many London schools have advantages for the teaching of the subject which outweigh the disadvantages arising from the distance from areas where actual field studies can be made.

Geology and Careers.

While the introduction of Geology into schools is advocated by the Committee chiefly on cultural grounds, it may be useful to give some indications of the nature of the posts available to qualified geologists.

Apart from those obtaining academic appointments and posts in museums, most graduates in Geology find positions in geological surveys at home or in the Empire, or on the staff of mining and oil companies in all parts of the world. Most of these posts involve much field work, sometimes in relatively unexplored countries, thus affording attractive opportunities for young men who are willing to undertake work abroad.

The number of posts of this kind is not of course large, but there is already a difficulty in finding sufficient students to fill the posts which are available. It is certain that there will be a still greater dearth of British-trained geologists in the near future, unless something is done to stimulate the entry of students into geological courses. Meanwhile, considerable numbers of geologists are being trained in American and German Universities, and they are filling the majority of posts in many parts of the world.

Quite apart, however, from the relatively limited number of students who may eventually make Geology their profession, it must be remembered that Geology forms a useful subsidiary subject for students training for different types of career in science, agriculture and engineering, and for administrative posts in India and the Colonies. It is ordinarily taken by University students pursuing courses in Civil Engineering, Mining and Metallurgy, but it may be urged that some knowledge of Geology is of the greatest value to many other scientific workers, having regard to the fact that the majority of materials used in industry are obtained from the earth’s crust, and to the wide range of applications of Geology to problems related to building and road materials, foundations, soils, drainage and water supply.

Although many students preparing for such careers will have opportunities for taking classes in Geology at the University, only a small proportion are likely to do so if their interest in the subject has not been aroused at school, for it is becoming increasingly rare for students entering the University to take up new subjects, owing to the high standard to which work in school subjects has been carried and to the exemptions from first-year University examinations which are thereby granted.

Moreover, it must be emphasised that only a small proportion of those who enter for the various school examinations pass on to University work; most of them take up posts in industry and commerce at once. Of these, a considerable proportion who have no further academic training obtain posts where they are sooner or later concerned with mining, building, engineering or other problems in which even a small acquaintance with geological matters would be of real assistance. In ordinary life, too, opportunities for using scientific knowledge are continually increasing.
in number; the applications of Geology are certainly not fewer or less important than those of other sciences.

Unless some work in Geology is introduced into school curricula, not only will there be a serious restriction in the numbers who will seek to take up Geology as a profession, but many who may later be concerned with the applications of Geology will hardly know of the existence of a science which has close contacts with their work.

Suggestions regarding Syllabuses.

It has been suggested to the Committee that some indication of the scope of the syllabuses proposed at the various stages of school work will be useful as a basis for future discussion. In preparing the following notes the Committee have received much generous help from teachers in several areas and in different types of schools, particularly from those who are teaching Geology at the present time.

The syllabuses given below are in outline only. It must be emphasised that the Committee would favour the greatest elasticity in the treatment of the subject; in Geology perhaps more than in any other science the neighbourhood of the school should determine the bias given to the teaching. Geology taught without proper regard to the phenomena which the pupil can observe and study for himself must become dull and unreal. Thus in a North Wales school slates may be given an amount of attention which would be out of place in Hampshire; the effects of glaciation would be studied in less detail in the south of England than elsewhere in Britain; the fossils which a pupil might be expected to recognise would differ to a great extent from one area to another.

It may be remarked also that the order in which various sections of the syllabuses are arranged below is not intended to suggest the order in which matters should be dealt with by the teacher. The arrangement of the sections may in some cases appear to give a logical scheme of study, but it is suggested that in the teaching of Geology a start should always be made with those phenomena which are most within the common experience of the children: the pebbles or stones they bring to school, handy rock exposures, the stones used in local buildings, the stream in the school grounds, the adjacent cliffs or shores.

General Elementary Science.

Much attention has lately been given to the development of courses in General Science both for Senior Elementary Schools and for Secondary Schools. The lack of any general understanding of the meaning of science, of its ideals or of its applications to modern life, has led to attempts to frame courses of instruction wider in scope than those commonly followed in the schools. In most of the schemes of General Science already in use, Physics, Chemistry and Biology are included; a few authorities have approved more extended syllabuses embodying a little Geology and in some cases a small amount of Astronomy.

The Committee feel that it is unnecessary in this Report to meet the various arguments put forward against the introduction of General Science into schools; the possibility that it may reduce the standard of attainment in one or more specialised sciences reached by pupils proposing to enter Universities is surely of less significance than the certainty that such a course will give to the much greater number of pupils whose formal training
will cease with school years an appreciation of the scope and aims of science, and an indication of its contacts with ordinary life.

The Committee therefore strongly support the view that instruction in General Science should form an essential part of a liberal education. They consider that more specialised instruction in individual science subjects could be given to pupils who wish later to devote themselves to science; this could be done either concurrently or at a later stage of school life.

The Committee would prefer to see a co-ordinated scheme of General Science in which the individual sciences are not sharply separated, and recognise that it may be desirable for a single teacher to deal with such a scheme rather than for experts in each branch to teach the separate sciences. It is of course probable that there are comparatively few teachers available at present who are capable of treating General Science effectively on these lines, but suitable teachers would soon be forthcoming if there were any considerable demand from the schools.

The syllabuses which have been suggested for courses in General Science have given rise to much discussion, but the Committee do not propose to enter into any consideration of the correct proportions in which the various sciences should be blended, believing that the proper content of General Science will be best determined after greater experience in teaching it, and by the interests of the individual teacher. The Committee believe, with many educationists, that a syllabus on the lines of the old Physiography (as understood by Huxley) but with more modern outlook, may eventually prove to be most suitable.

The Committee hold strongly, however, that a certain amount of Geology should be introduced into every scheme of General Science. The amount desirable is not very extensive, and it is suggested that the time devoted to it in such a scheme should not be more than one-sixth of the total time available for the course. This would not necessarily involve even so great a reduction in the other portions of the subject as might at first appear, for at many points the matter introduced in the sections of Chemistry, Physics and Biology is closely related to Geology, and by a very moderate extension can be given a much wider value. For example, most teachers of Chemistry in dealing with carbon dioxide and the carbonates make some reference to limestone and chalk, with perhaps some remarks on the origin of these rocks; at that point the pupils could be taken a little further towards an understanding of the bedded nature of the limestones, their contents and origin, and the reason for the occurrence of limestones of marine origin at considerable heights above the sea. Similarly most schemes of General Science make some reference to the evidence of evolution and to fossils; the contacts with Geology and a simple account of the history of life make small demand of additional time. Other parts of Geology are inseparable from physical geography. The teaching of science undoubtedly fails if it leaves the impression that the natural world is divided into separate and independent compartments.

The Committee consider that a General Science scheme should embrace the following topics:

Rocks: igneous and sedimentary rocks; the chief characters of granite, basalt, conglomerate, sandstone, clay, shale, slate, limestone and chalk, coal.

The common minerals, such as quartz, felspar, mica, rock salt, iron pyrites, an ore of iron such as hematite, calcite. (The composition of the more complex minerals should not be required unless in very
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general terms. Although some teachers of chemistry require the names of many more minerals to be learned, the Committee do not advocate this as part of General Science.)

Denudation: effects of frost, variation of temperature, gravitation, wind, rain, rivers, ice, waves; soil formation.

Deposition of sediments: types of modern sediment.

Hot springs and volcanoes (the latter not in any detail).

A general idea of the arrangement of rocks; their stratification; the sequence of animal fossils in earth history (to be treated in very broad outlines only).

As far as possible this course should be based on specimens collected locally and amplified by a study of the scenery of the school area.

The order in which these topics are treated ought to depend on the arrangement of the rest of the syllabus, the most suitable scheme involving the introduction of some of the Geology in connection with relevant aspects of other sciences.

First School Certificate.

While the inclusion of some Geology as part of a General Science course is probably the most effective way of introducing the subject into First School Certificate courses in Secondary Schools, there are certain schools where it may be advisable to institute courses in it as a full subject for the First Certificate. The subject is already taught very successfully at this stage in some schools, chiefly in South Wales, and there is no doubt that those pupils who are unlikely to carry the study of any science to a further stage benefit greatly from such training; in areas of outstanding geological interest and elsewhere there may be special reasons for the development of courses for the First Certificate for such pupils.

Syllabuses in Geology for the First School Certificate examination have been prepared by several examining bodies, and in general they are quite suitable. The Committee believe that the treatment of the subject at this stage should be less academic than for the Higher School Certificate or for first year University examinations, and that emphasis should be laid on matters which are likely to lie within the experience of school children. They would urge that a study of the school locality (or some other accessible area) should form an essential and considerable part of the course, and that candidates should be required to collect specimens, to make personal observations and to keep field note-books with sketches of local features if the area is suitable. Such wider aspects of Geology as the origin of the earth and the nature of the inner earth, an understanding of which must largely depend on observations which the pupils are unable to verify, should occupy a much less prominent place in the course.

In order to indicate the relative importance which the Committee would assign to the various divisions in the syllabus, the approximate proportion of the time available which it is suggested should be devoted to each is shown below.

The surface agents: atmosphere, water, ice, seas, weathering;
transportation of rock debris; alluvial and glacial deposits, flood plains and deltas; marine deposits. (20 per cent.)

An elementary study of common minerals: quartz and other forms of silica, felspar, mica, hornblende, augite, olivine, haematite, magnetite, pyrites, galena, zinc blende, calcite, dolomite, fluor spar, rock salt, gypsum. (10 per cent.)
Main types of sedimentary rocks: sandstone, grit, conglomerate, shale, clay, fireclay, marl, limestone, ironstone, coal.

Igneous rocks: granite, basalt, obsidian, porphyry. Volcanoes; lavas, ash and agglomerate.

Metamorphic rocks: illustrated by reference to slate, schist, gneiss, marble.

Structural geology: dip, strike, simple folds, faults, unconformity; boss, dyke, sill, neck. Practical work to include a study of very simple geological maps and drawing of sections across them.

Movement of earth's crust: raised beaches, submerged forests and drowned valleys; folding and faulting; folded mountains; rift valleys and block mountains.

Fossils and their uses: evidence of past climates and conditions of formation of sedimentary rocks; a general idea of the sequence of fossil vertebrates; the characteristic fossils of the main periods (e.g. Trilobites and Graptolites in the Lower Palaeozoic, Ammonites and Belemnites in the Mesozoic). The general characters of the main groups of fossils only to be required, rather than any names of genera (except possibly of fossils of importance in the locality); overloading of the course by lists of names to be avoided.

A general study of the character of the major rock groups of Britain, and of the scenic features to which they give rise (e.g. the slate groups of Wales and the Lake District, the Chalk areas, the Carboniferous Limestone, the Coalfields, etc.).

Local geology: a study of the features in the school area; examination of quarries and natural sections; observation of escarpments and river erosion and deposition. Simple field sketching should be encouraged. Study of local geological maps and of the physical features exhibited in Ordnance maps.

Practical work illustrating the above topics, included in the time allotted to the various sections. Simple tests of minerals, including hardness, density, solubility and reactions to dilute acid. The study of rocks and fossils, the study of maps and the construction of block models; field excursions. Other aspects of practical work are discussed below.

Higher School Certificate.

For the Higher School Certificate a syllabus is put forward for a course in Geology as a principal subject, to occupy approximately one-third of two years' school work. Some teachers may prefer to introduce Geology only as a subsidiary subject at this stage, in which case the syllabus would need to be reduced considerably as regards detail; others, while keeping it as a principal subject, may wish to make the sections dealing with physical geography identical with some portion of the Geography syllabus, so that when these two subjects are taken together they do not represent two complete principal subjects. It has appeared more useful, however, to design a syllabus which covers the whole range of the subject and thus preserves its essential unity.
The suggested syllabus has been made on the assumption that the pupils pursuing this course will have little previous knowledge of Geology; presumably the great majority will have done no more than it is proposed to include in the General Science syllabus. The course outlined is much wider in scope and should be more academic in approach than that proposed for the First School Certificate. It is suggested that the pupils should not only have some training in the recognition of rocks, minerals and fossils, and some knowledge of the varied applications of Geology, but that they should also learn something of the relation of Geology to other sciences, and of the more modern views of earth history. The course is designed rather for those completing their formal education in science than for those proposing to carry the study of Geology to a further stage.

The earth as a planet; its major surface features. Weathering in different climates; soil formation; denudation; marine erosion.

Sedimentary rocks; modern sediments; conditions of deposit as indicated by character of sediments. Marine, estuarine, deltaic, lacustrine and desert deposits among British strata.

The composition and characters of the common minerals (a more extended list than for First Certificate); some study of elementary crystallography including the use of Miller's notation.

Igneous rocks: general structure and classification, to include granite, syenite, diorite, gabbro, serpentine, quartz porphyry, porphyry, dolerite, rhyolite, obsidian, andesite, basalt.

Structural geology: stratification, lamination, dip, strike, outcrop, joints, cleavage. Relation of outcrop to the form of land. Types of folding. Faults, their effects on outcrops. Unconformity; overlap. Outliers and inliers.

Igneous activity: modes of occurrence of igneous rocks. Volcanoes; geographical distribution; types of eruption; forms of lava and ash deposits.

Earth movement. Elevation and depression of shore lines; mountain folding. Rifting and block movements. Earthquake phenomena; seismographic records. Structure of the inner earth; mean density of the earth; temperature of the interior.

Metamorphism; pneumatolysis.

Land forms: their development and relation to rock structure and climate; mountains, plateaux, plains, drainage systems. Escarpments; relation of valley systems to structure. Forms of coasts.

Fossils: their use in correlating sedimentary rocks. A general study of the evolution of fishes, reptiles and mammals. The characters of Foraminifera, Sponges, Graptolites, Corals, Crinoids, Echinoids, Brachiopods, Lamellibranchia, Cephalopoda, and Trilobites. The selection of fossils to be determined by the systems available for study near the school.

Principles of Historical Geology. Broad outlines of the structure of Great Britain. General characters of the different systems and the physical conditions under which they were deposited. The scenic features associated with various formations.


The practical work should be arranged to illustrate the above topics. It should include the examination of common minerals and rocks in hand
specimen (and where possible in the field), and of fossils. If the school possesses a microscope it can be used with advantage for the examination of rock slices; moreover, an ordinary microscope can now be converted at little cost into a polarising microscope, which would add greatly to the interest of examining rocks. The study of geological maps and the drawing of sections across them is an important part of the work; those selected should include geological maps of the district, to be studied in connection with field work. In the course of field work reference should be made to the structural features and their influence on relief; the position of springs; the relation of the soils and distribution of vegetation to the nature of the underlying rocks; building stones and other products of economic importance.

Senior (Elementary) Schools.

While the Committee believe that a well-planned scheme of General Science (including the elements of geological knowledge as outlined on p. 284) supplies the most suitable basis for science teaching in Senior Schools, they recognise that in some schools the facilities are inadequate for experimental work of the character desirable in such a scheme. Where work in science has to be more limited in scope it is suggested that Geology may suitably be introduced as an independent subject, for it has the advantage that it can be taught with very little equipment, and that its requirements as regards laboratories and apparatus are fewer than in the case of almost any other science. It would be appropriate to teach Geology more fully also in those areas where many of the scholars will eventually find employment in mines and quarries or on the land.

The courses provided in such schools would naturally show much variation, especially as the Senior Schools are free from the necessity of preparing their pupils for prescribed examinations. In most cases a rather practical bias would be appropriate to the course, and the relations of Geology to human life would be of outstanding importance; treated in this way Geology would form a link between the cultural and the vocational aspects of study. In some schools the approach to Geology would best be made through school journeys, which afford opportunities for simple field studies of a more extended character.

As an example of a scheme of study for Senior Schools the following is suggested:

1. An elementary study of rocks. Based mainly on material obtained or used locally, with comparative examination of other types. Local uses of rocks in building and brick making, for road materials, in industrial processes, etc.

2. The common minerals: (a) in relation to rocks examined; (b) some metallic ores, and the derivation from them of metals by simple experiments; (c) such minerals as rock salt, with reference to mode of origin, etc.

3. Bedding and jointing of rocks; structures of rocks as seen in the field; extent and underground occurrence.

4. Springs and spring water: mineral, medicinal and petrifying springs; hard and soft water. Water supply: how towns and villages are supplied.

5. Soil and its formation. Local soils and sub-soils, with observations on their distribution and thicknesses.
7. Volcanoes and earthquakes (treated in outline only).
8. Coal: its origin and distribution in Britain; fossil plants.
10. The main principles of historical geology, sufficient to give some indication of the length of geological time and an idea of a sequence of events in which, for example, the formation of coal and rock salt were episodes. Reference would be made to fossils here and at other suitable points in the course.
11. Geology and scenery, studied first in the school area, and then extended to other areas, such as chalk country, limestone areas, grit moors, etc.
   The geology of other features seen in the area such as cliffs, caves, landslips, beaches, sand dunes; the use of breakwaters and groynes.

It is suggested that where possible simple experiments should be carried out in connection with this course on the lines indicated below. Many of these experiments would form a useful introduction to work in other branches of science.

**Practical Work in Geology.**

It has been pointed out to the Committee that one reason why some teachers find difficulty in introducing Geology into science courses is the lack of suitable practical work. It is, of course, true that Geology is primarily an observational science, and the problem of keeping a large class actively observing (rather than doing) is one which may present serious difficulties to many teachers. It may be pointed out that some teachers have very successfully met this problem by requiring pupils to keep tabulated records of their observations on rocks and minerals, and to make neat drawings of fossils and crystals. There is, however, little doubt that certain pupils will be more interested to be doing some simple experiment, and the Committee suggest that without much difficulty a scheme of experimental work on the rocks and minerals could be devised. This could be developed to include such exercises as the following:

1. The identification of small samples of common minerals by simple tests based on information supplied in outline tables. For instance, instead of being given labelled specimens of quartz, calcite or gypsum for study, unlabelled samples could be determined by the pupils, using tests such as hardness, reaction with acids, etc. Blowpipe methods could be used with other minerals.
2. The study of some rocks could be linked with actual determinations of the proportions of their constituents; pupils could break up granite or other coarse igneous rocks, separate the constituents into heaps, and weigh them.
3. The constituents of sandstones and grits could be investigated by crushing samples and making simple separations of different grain sizes or of heavy minerals.
4. The solubility of limestones and determination of the percentage of insoluble matter; similarly the effects of hot and cold dilute acid on dolomites.
5. Measurement of the porosity of sandstones, chalk, etc.

6. Determinations of specific gravities of rocks and minerals.

These experiments could be developed, especially in a course of General Science. One advantage is that they require little equipment and only a small space. While they may be used to supplement observational work and to enliven the ordinary laboratory work to some extent in the early stages, these experiments cannot entirely displace the examination and sketching of material. In any case field work must form an essential part of almost any geological course.

The practical work related to map study may also be extended by the construction of simple block models to illustrate structures. Rectangular models to show true and apparent dips and outcrops, or folds in plan and section, can be built up in paper very easily; it is very helpful for pupils to make a variety of these at an early stage.

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REPTILE-BEARING OÖLITE, STOW.

Report of Committee appointed to investigate the reptile-bearing oölite near Stow-on-the-Wold, subject to the condition that suitable arrangements be made for the disposal of the material (Sir A. SMITH WOODWARD, F.R.S., Chairman; Mr. C. I. GARDINER, Secretary; Prof. S. H. REYNOLDS, Mr. W. E. SWINTON).

The two quarries in the Chipping Norton Limestone near Stow-on-the-Wold, from which reptilian remains have been obtained before, have been visited from time to time and the reptilian remains found there brought away and sent to London for extraction and restoration. Most of them are now in the Stroud Museum.

Of the four groups of reptiles represented—Crocodile, Theropod, Sauropod and Carnivorous Dinosaurs—all but the last one are in the series collected since the issue of the previous report of the Committee. They include:

**Crocodiles.**—Several vertebrae and a nearly perfect scapula.

**Theropod Dinosaurs.**—An ilium, a sacrum and a right femur, this last being in an almost perfect condition and the finest bone in the series.

**Sauropod Dinosaurs.**—An enormous caudal vertebra, an almost perfect right coracoid and two ischia.

Professor Reynolds is studying the specimens and hopes shortly to publish a description of them. The Committee is unanimously of opinion that an application for a further grant should be made.
ARTEMIA SALINA.

Report of the Committee appointed to investigate the progressive adaptation to new conditions in Artemia salina (Diploid and Octoploid, Parthenogenetic v. Bisexual) (Prof. R. A. Fisher, F.R.S., Chairman; Dr. K. Mather, Secretary; Dr. J. Gray, F.R.S., Dr. F. Gross, Dr. E. S. Russell, O.B.E., Prof. D. M. S. Watson, F.R.S.).

During the year experiments have been carried out on 16,540 tested nauplii, distributed in five lines, of which two have been carried to the fifth, one to the fourth, and the remaining two to the third, selected generation. Table I shows the number of tested nauplii in each generation of each line.

Table I.

<table>
<thead>
<tr>
<th>Generation</th>
<th>Line.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C2</td>
</tr>
<tr>
<td>Unselected</td>
<td>260</td>
</tr>
<tr>
<td>1st selected</td>
<td>387</td>
</tr>
<tr>
<td>2nd do.</td>
<td>225</td>
</tr>
<tr>
<td>3rd do.</td>
<td>57</td>
</tr>
<tr>
<td>4th do.</td>
<td>—</td>
</tr>
<tr>
<td>5th do.</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>929</td>
</tr>
</tbody>
</table>

The large increase in the extent of the experiments as compared with previous years is due partly to the increased amount of time devoted to the care of the cultures by Miss North and other members of the Galton Laboratory, and partly to greater success in obtaining broods, especially during the winter and spring months. More intense illumination may have been one factor contributing to this success.

The experiments have followed the programme, as originally laid down, of testing each brood in six successive standard strengths of sodium arsenite and selecting, in each generation, survivors from the higher strengths for use as parents. Although, as will be seen, remarkable progressive changes in tolerance were shown in several lines, the difficulty, noted in previous reports, of broods from the same parents showing very unequal mortalities has not yet been overcome. For example, we give in Table II the number tested and surviving at different strengths in two large broods occurring in succession in the unselected generation of C6. It will be observed that

Table II.

<table>
<thead>
<tr>
<th>Strength of Solution</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>O</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brood 1 Tested</td>
<td></td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td></td>
<td>112</td>
</tr>
<tr>
<td>Surviving</td>
<td></td>
<td>16</td>
<td>12</td>
<td>15</td>
<td>18</td>
<td>18</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brood 2 Tested</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>24</td>
<td>24</td>
<td>156</td>
</tr>
<tr>
<td>Surviving</td>
<td>6</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
equivalent mortalities in these two broods occur at concentrations differing by some eight units, representing a difference of more than two-fold in the concentration of the poison. The technique adopted of subdividing each brood into six successive strengths, while adequate to cope with small inequalities in resistance between broods, is quite inadequate to yield intelligible results so long as differences of the magnitude illustrated continue to occur. Such differences, moreover, undermine the efficacy of the selective process, by which the parents are chosen, by allowing relatively susceptible individuals from broods in which the survival rate has happened to be high to be mistaken for individuals which have themselves displayed high resistance.

The stage which the research has now reached is, therefore, primarily

one of the improvement of the technique of experimental elimination to a level of efficiency comparable with that already attained in propagation. The stricter control of water temperature and of food density during the test period and of the possibility that some broods would show a considerable mortality even without toxic elimination, are the three methods now being tried to improve this aspect of our procedure.

Nevertheless, it is obvious from the records that substantial changes in resistance, such as cannot be ascribed to accidental differences, have occurred in at least four out of the five lines, the improvement being often continued progressively from generation to generation. The data from line C6 are shown in Table VIII (at the end of the report) the changes in the estimated concentration for 50 per cent. mortality being given in Table IV, and shown diagrammatically in Fig. 1.

In contrast, no appreciable progress whatever has been achieved in the parallel line C4, for which the estimated 50 per cent. death points are given in Table V. There has been, superficially, a drop in resistance in this line.
The 3rd selected generation may be ignored owing to insufficient data, as shown by the large standard error, but the decrease in resistance of the $S_2$ generation seems to be real.

The different behaviour of these two lines might be ascribed to the possibility that in the latter no genetic variability affecting survival in the test condition was present, whereas in $C_6$ great differences in genotype were at first available, leading to a rapid selective response. We suggest, however, that, as each generation may be predominantly bred from so few as three pairs of parents, the element of chance in the selection of these latter may be the more important factor in causing discrepancy. On this view in the one line selection has been successful in securing parents of high innate resistance for the propagation of the stock, while in the second case parents of mediocre or low resistance have happened to be selected owing to unintentional inequality of the conditions to which different broods have been subjected.

**Table III.**

<table>
<thead>
<tr>
<th>Generation</th>
<th>50 per cent. Death Point</th>
<th>Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unselected</td>
<td>$8.791 \pm 0.742$</td>
<td>0.179</td>
</tr>
<tr>
<td>1st selected</td>
<td>$10.242 \pm 0.257$</td>
<td>0.258</td>
</tr>
<tr>
<td>2nd do.</td>
<td>$11.090 \pm 0.227$</td>
<td>0.310</td>
</tr>
<tr>
<td>3rd do.</td>
<td>$11.763 \pm 0.240$</td>
<td>0.359</td>
</tr>
<tr>
<td>4th do.</td>
<td>$13.396 \pm 0.314$</td>
<td>0.396</td>
</tr>
<tr>
<td>5th do.</td>
<td>$11.150 \pm 0.382$</td>
<td>0.326</td>
</tr>
</tbody>
</table>

**Table IV.**

<table>
<thead>
<tr>
<th>Generation</th>
<th>50 per cent. Death Point</th>
<th>Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unselected</td>
<td>$8.524 \pm 0.543$</td>
<td>0.245</td>
</tr>
<tr>
<td>1st selected</td>
<td>$7.436 \pm 0.132$</td>
<td>0.316</td>
</tr>
<tr>
<td>2nd do.</td>
<td>$4.675 \pm 0.427$</td>
<td>0.224</td>
</tr>
<tr>
<td>3rd do.</td>
<td>$0.761 \pm 5.474$</td>
<td>0.061</td>
</tr>
</tbody>
</table>

The behaviour of some of the other lines seems to confirm this view. (See Tables V–IX.)

A feature of some interest is shown by the steepness of the gradient of mortality with respect to poison concentration (called the regression in Tables IV and V). Other things being equal, this gradient will be higher the more uniform the material. In line $C_6$ it may be observed that the regression increases in successive generations as the resistance is heightened. In other lines it also appears that, when an advance has been made, by selection, it is generally accompanied by an increase in the regression. It would appear that the increase in genetic resistance is generally accompanied by a decrease in variability, or, in other words, that the stocks are becoming more homozygous for the genes favoured by the selection. In view of this effect it will be of especial interest to cross the two lines now available after five generations of selection, and to determine whether the variability is thereby restored without loss of resistance.

The Committee asked to be reappointed with a grant of £20.
REPORTS ON THE STATE OF SCIENCE, ETC.

Table V.
Line C2.

<table>
<thead>
<tr>
<th>Solution</th>
<th>S₀</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (5)</td>
<td>24 T</td>
<td>24 S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F (6)</td>
<td>34 T</td>
<td>21 S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G (7)</td>
<td>45 T</td>
<td>32 S</td>
<td>19 T</td>
<td>10 S</td>
</tr>
<tr>
<td>H (8)</td>
<td>51 T</td>
<td>28 S</td>
<td>48 T</td>
<td>23 S</td>
</tr>
<tr>
<td>I (9)</td>
<td>26 T</td>
<td>15 S</td>
<td>61 T</td>
<td>47 S</td>
</tr>
<tr>
<td>J (10)</td>
<td>38 T</td>
<td>23 S</td>
<td>61 T</td>
<td>30 S</td>
</tr>
<tr>
<td>K (11)</td>
<td>32 T</td>
<td>16 S</td>
<td>62 T</td>
<td>34 S</td>
</tr>
<tr>
<td>L (12)</td>
<td>20 T</td>
<td>7 S</td>
<td>65 T</td>
<td>8 S</td>
</tr>
<tr>
<td>M (13)</td>
<td>44 T</td>
<td>3 S</td>
<td>48 T</td>
<td>27 S</td>
</tr>
<tr>
<td>N (14)</td>
<td>17 T</td>
<td>0 S</td>
<td>33 T</td>
<td>5 S</td>
</tr>
<tr>
<td>O (15)</td>
<td>10 T</td>
<td>0 S</td>
<td>19 T</td>
<td>6 S</td>
</tr>
</tbody>
</table>

In the case of each generation the first column (T) gives the numbers of nauplii tested, and the second column (S) the numbers of survivors.

Table VI.
Line C3.

<table>
<thead>
<tr>
<th>Solution</th>
<th>S₀</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>C (3)</td>
<td>12 T</td>
<td>12 S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D (4)</td>
<td>12 T</td>
<td>4 S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E (5)</td>
<td>66 T</td>
<td>48 S</td>
<td>8 T</td>
<td>8 S</td>
</tr>
<tr>
<td>F (6)</td>
<td>86 T</td>
<td>43 S</td>
<td>8 T</td>
<td>7 S</td>
</tr>
<tr>
<td>G (7)</td>
<td>111 T</td>
<td>50 S</td>
<td>33 T</td>
<td>19 S</td>
</tr>
<tr>
<td>H (8)</td>
<td>107 T</td>
<td>33 S</td>
<td>66 T</td>
<td>41 S</td>
</tr>
<tr>
<td>I (9)</td>
<td>113 T</td>
<td>31 S</td>
<td>66 T</td>
<td>33 S</td>
</tr>
<tr>
<td>J (10)</td>
<td>113 T</td>
<td>31 S</td>
<td>75 T</td>
<td>26 S</td>
</tr>
<tr>
<td>K (11)</td>
<td>49 T</td>
<td>1 S</td>
<td>67 T</td>
<td>20 S</td>
</tr>
<tr>
<td>L (12)</td>
<td></td>
<td></td>
<td>67 T</td>
<td>29 S</td>
</tr>
<tr>
<td>M (13)</td>
<td></td>
<td></td>
<td>40 T</td>
<td>9 S</td>
</tr>
<tr>
<td>N (14)</td>
<td></td>
<td></td>
<td>22 T</td>
<td>1 S</td>
</tr>
<tr>
<td>O (15)</td>
<td></td>
<td></td>
<td></td>
<td>6 S</td>
</tr>
</tbody>
</table>

In the case of each generation the first column (T) gives the numbers of nauplii tested, and the second column (S) the numbers of survivors.
### Table VII.
**Line C₄.**

<table>
<thead>
<tr>
<th>Solution</th>
<th>( S₀ )</th>
<th>( S₁ )</th>
<th>( S₂ )</th>
<th>( S₃ )</th>
<th>( S₄ )</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (4)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>94</td>
<td>51</td>
</tr>
<tr>
<td>E (5)</td>
<td>5</td>
<td>3</td>
<td>25</td>
<td>134</td>
<td>60</td>
</tr>
<tr>
<td>F (6)</td>
<td>5</td>
<td>3</td>
<td>52</td>
<td>150</td>
<td>73</td>
</tr>
<tr>
<td>G (7)</td>
<td>5</td>
<td>5</td>
<td>52</td>
<td>142</td>
<td>78</td>
</tr>
<tr>
<td>H (8)</td>
<td>5</td>
<td>4</td>
<td>106</td>
<td>172</td>
<td>107</td>
</tr>
<tr>
<td>I (9)</td>
<td>4</td>
<td>4</td>
<td>106</td>
<td>171</td>
<td>78</td>
</tr>
<tr>
<td>J (10)</td>
<td>4</td>
<td>3</td>
<td>130</td>
<td>116</td>
<td>39</td>
</tr>
<tr>
<td>K (11)</td>
<td>-</td>
<td>130</td>
<td>15</td>
<td>112</td>
<td>39</td>
</tr>
<tr>
<td>L (12)</td>
<td>75</td>
<td>4</td>
<td>55</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>M (13)</td>
<td>21</td>
<td>1</td>
<td>11</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>N (14)</td>
<td>21</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>O (15)</td>
<td>21</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

In the case of each generation the first column (T) gives the numbers of nauplii tested, and the second column (S) the numbers of survivors.

### Table VIII.
**Line C₆.**

<table>
<thead>
<tr>
<th>Solution</th>
<th>( S₀ )</th>
<th>( S₁ )</th>
<th>( S₂ )</th>
<th>( S₃ )</th>
<th>( S₄ )</th>
<th>( S₅ )</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (5)</td>
<td>2</td>
<td>2</td>
<td>14</td>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>F (6)</td>
<td>11</td>
<td>10</td>
<td>61</td>
<td>48</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>G (7)</td>
<td>11</td>
<td>10</td>
<td>101</td>
<td>76</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>H (8)</td>
<td>98</td>
<td>46</td>
<td>106</td>
<td>83</td>
<td>93</td>
<td>72</td>
</tr>
<tr>
<td>I (9)</td>
<td>130</td>
<td>61</td>
<td>109</td>
<td>71</td>
<td>128</td>
<td>95</td>
</tr>
<tr>
<td>J (10)</td>
<td>130</td>
<td>54</td>
<td>170</td>
<td>101</td>
<td>140</td>
<td>94</td>
</tr>
<tr>
<td>K (11)</td>
<td>128</td>
<td>40</td>
<td>163</td>
<td>68</td>
<td>168</td>
<td>94</td>
</tr>
<tr>
<td>L (12)</td>
<td>119</td>
<td>34</td>
<td>102</td>
<td>25</td>
<td>164</td>
<td>73</td>
</tr>
<tr>
<td>M (13)</td>
<td>121</td>
<td>35</td>
<td>94</td>
<td>39</td>
<td>146</td>
<td>36</td>
</tr>
<tr>
<td>N (14)</td>
<td>58</td>
<td>12</td>
<td>95</td>
<td>14</td>
<td>72</td>
<td>13</td>
</tr>
<tr>
<td>O (15)</td>
<td>24</td>
<td>0</td>
<td>67</td>
<td>4</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>P (16)</td>
<td>-</td>
<td>-</td>
<td>27</td>
<td>0</td>
<td>24</td>
<td>3</td>
</tr>
</tbody>
</table>

In the case of each generation the first column (T) gives the numbers of nauplii tested, and the second column (S) the numbers of survivors.
Table IX.
Line C7.

<table>
<thead>
<tr>
<th>Solution</th>
<th>$S_0$</th>
<th>$S_1$</th>
<th>$S_2$</th>
<th>$S_3$</th>
<th>$S_4$</th>
<th>$S_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C (3)</td>
<td>6 3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>D (4)</td>
<td>6 5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>E (5)</td>
<td>97 43</td>
<td>16 16</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>F (6)</td>
<td>173 84</td>
<td>67 56</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>G (7)</td>
<td>200 88</td>
<td>107 65</td>
<td>15 12</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>H (8)</td>
<td>202 72</td>
<td>131 73</td>
<td>38 31</td>
<td>—</td>
<td>17 10</td>
<td>72 53</td>
</tr>
<tr>
<td>I (9)</td>
<td>205 58</td>
<td>161 101</td>
<td>85 59</td>
<td>28 23</td>
<td>139 38</td>
<td>118 55</td>
</tr>
<tr>
<td>J (10)</td>
<td>162 50</td>
<td>187 82</td>
<td>123 81</td>
<td>49 34</td>
<td>199 71</td>
<td>175 40</td>
</tr>
<tr>
<td>K (11)</td>
<td>95 33</td>
<td>167 53</td>
<td>142 98</td>
<td>61 46</td>
<td>204 55</td>
<td>199 30</td>
</tr>
<tr>
<td>L (12)</td>
<td>40 5</td>
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In the case of each generation the first column (T) gives the numbers of nauplii tested, and the second column (S) the numbers of survivors.

**Zoological Record.**

Report of Committee appointed to co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the ‘Zoological Record’ (Sir Sidney Harmer, K.B.E., F.R.S., Chairman; Dr. W. T. Calman, C.B., F.R.S., Secretary; Prof. E. S. Goodrich, F.R.S., Prof. D. M. S. Watson, F.R.S.).

The grant of £50 was paid over to the Zoological Society on June 25, 1937, as a contribution towards the cost of preparing and publishing Volume LXXII of the Zoological Record for 1935. Referring to the ‘Record Fund’ the report of the Council of the Zoological Society for 1936 states: ‘It will be seen that the position has not improved, and the loss on each volume is still very heavy, much in excess of the contribution of £500 per annum made by this Society, so that unfortunately the Reserve Fund stands lower at December 31st than it did at the end of the previous year.’ It appears from this that no progress is evident in the direction of making the Record self-supporting and that only a continuance of help from the various contributing societies will ensure the continuation of this indispensable publication. The Committee accordingly asks for reappointment, with the renewal of the grant of £50.
FRESHWATER BIOLOGICAL STATION, WINDERMERE.

Report of Committee appointed to aid competent investigators selected by the Committee to carry out definite pieces of work at the Freshwater Biological Station, Wray Castle, Windermere (Prof. F. E. Fritsch, F.R.S., Chairman; Prof. P. A. Buxton, Secretary; Miss P. M. Jenkin, Dr. C. H. O'Donoghue (from Section D); Dr. W. H. Pearsall (from Section K).

During the current year the British Association’s table at the laboratory has been occupied by Mr. R. Misra, working under the general direction of Dr. W. H. Pearsall of the University of Leeds. Mr. Misra has carried out his work in close collaboration with members of the Association’s staff. A full account of his work has been prepared for publication as a scientific paper. The following short account of the work has been drawn up by Mr. Misra.

LAKE MUDS AND THEIR PLANT SUCCESSIONS.

Under the guidance of Dr. W. H. Pearsall this subject has been studied in the Lake District during a period of two years. The investigations were carried out in the Freshwater Biological Laboratory for the two summers 1935–36, and the rest of the period has been occupied in chemical analysis of field collections at the University of Leeds.

It has been shown during my work that the plants attached to lake bottoms are greatly influenced by the nature of the substratum; their successions have been traced to chemical and physical changes taking place in the mud. In shallow water Littorella and Lobelia give way to Phragmites as the bottom gets older and more organic, and in deeper water Isoëtes gives place first to pond weeds, then to water-lilies, and finally to sedges as similar changes take place in the mud. These changes in the lake floor are therefore very important in deciding the quality and quantity of vegetation in a lake.

During the development of a plant succession, the lake muds do not become very acid as do terrestrial soils undergoing similar changes in the same district; for instance, in young or newly-colonised muds the pH range is very wide. But the pH range for organic muds is very narrow, the average figure being 5.8–6.0. Since the organic muds become extremely acid upon exposing them to air for some time, it is believed that the acidity under water is kept down by special types of anaerobic decomposition.

The ammonium thiocyanate test for detecting soil sourness was developed by Comber, and is frequently used by agriculturists for that purpose; but it would not work with lake muds, for it depends upon the presence of ferric iron, and in lake muds the iron is present in a reduced condition. This method has now been modified to apply to lake muds. This is done by oxidising the iron by hydrogen peroxide. A large number of samples studied by the modified technique show that the muds become deficient in lime as they accumulate organic matter. Plants like Littorella and Isoëtes cannot grow upon these lime-deficient muds, although the pond weeds do well there.
Decomposition of organic matter in the mud has been studied in some detail. Starting from bare sand or silt it has been shown that as the organic matter increases in the mud there is an increasing loss of carbon in the form of marsh gas and possibly some carbonic acid gas, whereas the nitrogen is retained upon the finely divided particles of mud in the form of ammonia. This process increases the fertility of the lake bottom up to about 25 per cent. organic content. Should the organic matter exceed this limit decomposition is retarded and subaqueous peat is formed, which may remain sterile or be colonised by sedges. As these changes progress the mud loses calcium available for plant growth, and iron and aluminium become the replaceable ions, while sulphides also accumulate; all these substances are toxic to many of the pond weeds. An analysis of plants collected in nature showed corresponding changes with regard to these elements. Many species were also transplanted to glass jars containing the different types of muds and sunk in the lake. The crops produced from them confirmed the above conclusions.

Further methods have been evolved, including electrical appliances to measure the reducing property of muds; it has been shown that the reducing property becomes stronger with increasing organic content; as a result, when the muds are kept in contact with water, the oxygen dissolved in the water is rapidly used up. This is a fact of great biological importance, for it means that organisms in the muds must live under anaerobic conditions.

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CYTOLOGY AND GENETICS.

Report of co-ordinating committee for Cytology and Genetics (Prof. Dame Helen Gwynne-Vaughan, G.B.E., Chairman; Dr. F. W. Sansome, Secretary; Prof. F. T. Brooks, F.R.S., Prof. E. A. E. Crew, Dr. C. D. Darlington, Prof. R. A. Fisher, F.R.S., Mr. E. B. Ford, Prof. R. R. Gates, F.R.S., Dr. C. Gordon, Dr. Hammond, Dr. J. S. Huxley, Dr. T. J. Jenkin, Dr. K. Mather, Dr. W. B. Turrill, Dr. C. H. Waddington.

Since cytology and genetics are the concern of more than one Section of the Association, the Committee was formed in 1936 to assist Organising Committees and Recorders in arranging joint sessions and in ensuring that papers of common interest were not given at the same time in different Sections.

The Committee realise that many of the facts of cytology and genetics are not readily assimilated by workers in other biological fields and that the difficulty is enhanced by the development of a specialised terminology. They therefore approached the Organising Committee of Sections D and K with a suggestion that a morning should be devoted to a joint symposium and arranged for the presentation of coherent accounts of recent work in their subjects in such a way as to avoid unnecessary technicalities. The Organising Committee have approved this proposal. Should it be successful, the Committee believe that the formation of such symposia and the presentation of cytological and genetical demonstrations will form an important part of their duties, and will be of value to the members of the Association.

A number of papers have been grouped in the above-mentioned symposium, a second series are associated in the form of a discussion on Genetics
and Taxonomy. The Committee therefore hope that they have made a useful step in the required direction and desire to place on record their appreciation of the encouragement and aid they have received from the Secretariats of the Sections concerned.

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KENT'S CAVERN.

Report of Committee appointed to co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern (Sir A. Keith, F.R.S., Chairman; Prof. J. L. Myres, O.B.E., F.B.A., Secretary; Mr. M. C. Burkitt, Miss D. A. E. Garrod, Mr. A. D. Lacaille).

Report on Excavations at Kent's Cavern.

The following report has been received from the excavators:

'The season 1936-7 lasted from September 15, 1936, to March 29, 1937, and excavating work was carried on in the "Vestibule" during forty-eight days. On December 28 the searching party had the assistance of Prof. R. Ruggles Gates, F.R.S. The area in which digging was continued was much the same as last year, but the excavators were successful in penetrating to a depth about 30 ft. below the datum line, which is about 8 ft. lower than was reached last season. On the way down, several large limestone rocks were met, which had to be broken up and removed as the work progressed; but fortunately it was found that more mammalian remains than usual were discovered at the lowest point. Flints have been rather scarce, only one of the Levallois type and a few Aurignacian being discovered. Teeth and bones have both been numerous, the remains of hyena being especially in evidence, outnumbering even those of the horse, the most outstanding being the skull of an adult hyena with twelve teeth in position; a pre-antepenultimate milk molar of a mammoth with the grinding surface well worn, also a true molar weighing two pounds and a portion of the mandible of a very young mammoth, including the symphysis; the left ramus of a bison's jaw, which is believed to be the longest jaw ever found in the Cavern; large portions of jaws of Irish deer; a distal pair of vestigial metacarpals, and part of the sternum of a reindeer; but the most interesting find was a large piece of the palmate portion of a deer's antler, found at a depth of nearly 30 ft., which is not yet identified, although it presents certain features similar to some antlers of reindeer.'

(Signed) ARTHUR H. O'GILVIE, E. H. ROGERS, B. N. TEBBS.

The Committee asks to be reappointed, with a further grant.
DERBYSHIRE CAVES.

Fifteenth Interim Report of Committee appointed to co-operate with a Committee of the Royal Anthropological Institute in the exploration of Caves in the Derbyshire District (Mr. M. C. Burkitt, Chairman; Mr. A. Leslie Armstrong, Secretary; Prof. H. J. Fleure, F.R.S., Miss D. A. E. Garrod, Dr. J. Wilfrid Jackson, Prof. L. S. Palmer, Mr. H. J. E. Peake).

Creswell Crags.—Mr. Leslie Armstrong, F.S.A., reports as follows:

‘Boat House Cave.—The work here has proved both arduous and baffling owing to unexpected difficulties encountered. In my last report reference is made to the removal of material introduced into the cave as puddling, when the embankment of the adjoining lake was constructed. This averages 6 ft. in thickness, two-thirds of it being stiff red clay. At the time of writing the 1936 report what was assumed to be breccia, or stalagmite, covering the floor of the cave, had been reached over a small area, but further excavation revealed that this substance was concrete laid down before the introduction of the puddled clay, and not stalagmite. As the work proceeded this concrete was found to rise along the side of the cave in a series of 12-in. steps and to extend in the form of a wall, 2 ft. thick and 5 ft. in height, across the entrance. Owing to its thickness and consistency, the concrete on the floor resisted all efforts to break through it by means of wedges and chisels and, ultimately, blasting has had to be resorted to. For the carrying out of this I am indebted to the Bolsover Colliery Company and to the Manager of the Creswell Colliery, who kindly furnished the necessary drilling machine and explosives and permitted one of their expert shot firers to do the blasting. An area of 6 ft. by 2 ft. 6 in. of the floor concrete has been removed in this manner and the underlying cave earth is now exposed in readiness for excavation. A superficial examination of the cave earth after the final shot yielded a mineralised bone, apparently reindeer, and other material which indicates that it is true cave earth. The whole of the material overlying the concrete has now been removed and its surface is exposed over half the area of the cave; therefore a systematic examination of the cave earth can be proceeded with and will shortly be undertaken.

‘The Yew Tree Shelter.—This is situated on the north side of the Gorge, opposite to the Boat House Cave. As the work in the Boat House did not require constant supervision, the excavation of this extensive rock shelter, which has been awaiting a suitable opportunity, was commenced in the autumn of 1936 and is still in hand. A sparse, but consistent, occupation is revealed which, in general character, appears to be contemporary with that of the Lower Middle and Middle zones of Mother Grundy’s Parlour. One quartzite implement, from the base of the deposit, is of Mousterian type. The occupation of the site was an occasional and not a constant occupation, but the abundance of pot boilers and burnt flints indicate that it was a living and not merely a workshop site. The associated fauna, so far recovered, includes mammoth, reindeer, horse, bison and hyæna.

‘112 sq. ft. have been completely excavated and the upper layer over a further 70 sq. ft. examined.

‘Whalley Rock Shelter.—In January, Dr. Arthur Court, of Chesterfield, brought to my notice a small rock shelter at Whalley, situated geographically
between Creswell Crags and Langwith Cave, and he co-operated with me in excavating it during May and June last. This proved to be a workshop site and yielded 160 artifacts. In general facies and in the fauna, this site agrees with the Creswell rock shelters and is contemporary in date therewith.

'A special exhibition of the whole of the artifacts and a representative selection of animal remains, obtained in the Pin Hole Cave and Mother Grundy’s Parlour excavations, was displayed at the British Museum from November 1936 to May 1937.

'Thanks are extended to Mr. Reginald A. Smith, F.S.A., Keeper of the Department of British and Medieval Antiquities, for providing the facilities and arranging this exhibition.

'A further grant is earnestly requested by the Committee for the continuation of the work in the Boat House Cave and at the Yew Tree rock shelter, Creswell.'

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MINING SITES IN WALES.

Report of Committee appointed to investigate early mining sites in Wales (Mr. H. J. E. Peake, Chairman; Mr. Oliver Davies, Secretary; Prof. V. Gordon Childe, Dr. C. H. Desch, F.R.S., Mr. E. Estyn Evans, Prof. H. J. Fleure, F.R.S., Prof. C. Daryll Forde, Sir Cyril Fox, Dr. Willoughby Gardner, Dr. F. J. North, Mr. V. E. Nash Williams).

The committee reports that excavations have been carried out in the spring and summer of 1937 on a number of ancient mining-dumps in Wales.

At Cwm Ystwyth permission to excavate was most kindly granted by Mr. Fermanoglu. The tips below the opencast at the top of the Comet Lode on Copper Hill were sectioned in several places. They were found to have been carefully picked over in ancient times, so that they contained little quartz or galena. On them are a great number of formless stone hammers, usually with marks of pounding at one end, while the sides are finely polished as a result of their use as mullers. They are always slightly broken, perhaps to obtain a good grip. They are made of a local rock, which, however, does not occur commonly, and was clearly sought for its hardness. There was also found part of a saddle quern. These tools differ from those which occur on the tips below the main opencast and on the ‘Roman Dumps’ at the Kingsland Lode. There one finds cup-marked stones used for pounding, but hammers do not occur and must have been of iron. The Kingsland Lode is known to have been exploited as late as 1800, and the cup-marked querns may therefore be attributed to the seventeenth or eighteenth century. The age of the workings and tools on the Comet Lode could not be determined, but they are clearly considerably older. At the same time the narrow chisel-cut galleries in the region of the main opencast, though of a type which might be considered Roman in South Europe, probably belong to a more recent period in Wales. It thus appears that the earliest miners at Cwm Ystwyth attacked one rather small outcrop in a large mineralised area. This careless neglect of the greater part of an ore-deposit is characteristic of the users of stone hammers in West Wales.

A small test was carried out on the ancient dump at Nantyreira. There were found three thick charcoal strata separated by layers of stones and mud, and overlying a deep bank of stones which rested directly on till. In
the lowest layer were several formless polished stone hammers. These did not occur at higher levels, and the charcoal layers may be more recent; perhaps the earliest miners worked by fire-setting, and their successors, in cleaning out the opencast, threw out the charcoal which was reposing in it. The extent of the prehistoric workings seems to have been small. Though chalcopyrite occurs at Nantyreira, the only ore found in the dumps was galena and cerussite, and even this was rare.

A thorough examination of the mine at Newtown was made with the permission of Mr. F. Bennett Lloyd of the Celynog Estate Office. It has long been known that there were old workings in Newtown Park, consisting of a shaft and gallery. A lower adit, just above the river-level, is now closed. The upper gallery has partly fallen in; it cannot be followed very far, and it branches on both sides. In the loose material of the floor was found what seemed to be a circular chipped stone lid, such as are common in Wales but difficult to date. Further evidence was, however, obtained from the river-bank. The hill rises steeply, and immediately below it a soft yellow layer, resembling denuded material, overlies stiff yellow clay, probably boulder-clay in situ, which hardly emerges above the level of the water. In the upper yellow layer were found fragments of slag and fused furnace lining; half-way up the hill was a fragment of metallic lead. These then appear to be derived from a hilltop furnace, whose exact site could not be located. It must clearly antedate the introduction of water-driven bellows, and is not improbably Roman, as we have evidence for the intensive Roman occupation of the Upper Severn Valley and their interest in the mineral resources of the district (e.g. slag and ore specimens from Caersws and Forden).

Fresh evidence for the chronology of stone mining-tools has recently been provided by a small excavation on a Roman tip on Parys Mt. and by a preliminary survey of the Llandudno area. At the former the lowest levels contain no stone tools and much quartz, and are clearly derived from primitive working. The upper levels had many stone tools used as hammers, mullers and querns. Mr. Fanning Evans reports the discovery on the mountain of a proper saddle-quern, such as accompany stone hammers at Cwm Ystwyth. Formless hammers found on the dumps at Great Orme's Head exactly resemble those from Cwm Ystwyth. There is good evidence for dating the Orme's Head mines to the later Roman period, and Parys was probably exploited at the same time, though it is not unlikely that it did not close down until after the Roman era. It thus appears that the formless hammer-muller-quern is Roman, and we may therefore provisionally assign to this period Cwm Ystwyth and the group of early workings round Plynlimon, as has long been suspected but has not been previously proved.

The Orme's Head mines also yielded a stone muller of the shape of a flattened sphere with a thumb-hole. Tools of this type are figured by Evans, but little was known of their date. The Roman dumps appear extensive, and are only partially covered by modern refuse; it is hoped later to carry out a detailed survey of them.

From somewhere in the Trecastell mine Mr. Trevethan reports a large perforated stone hammer. Near the bottom of the hill were found several unperforated smoothed stone hammers, differing from the previous group in having a slight rill for a handle. They had almost certainly been washed down from an old series of tips at the first and second levels. The workings corresponding to these tips have been cut with iron gads, and it is almost certain that the ore was extracted on wheeled trolleys or sledges. The latter feature seems medieval in all parts of Europe. The former are not known at any Roman mine in Wales save Dolaucothy, which is stylistically advanced probably because it was a state-directed enterprise. Thus we
may probably assign Trecastell to post-Roman times, and as it is known to have been vigorously exploited in the early seventeenth century, perforated and rilled hammers seem to have continued in use until that date. This conclusion is borne out by the late date of the roughly rilled hammers from Alderley Edge.

The objects from Cwm Ystwyth have been sent to the National Museum of Wales. Those from the Montgomeryshire mines have been deposited at Welshpool and a full report of these excavations will be published in the Montgomery Collections of the Powysland Club. The hammers from near Llandudno have been sent to Cardiff, save for one specimen which has been left in the Llandudno Museum; those from Parys have been sent to Bangor Museum.

The following rough ore-analyses have been carried out at Belfast:

(a) Chalcopyrite, Nantyreira: Cu 28·71 per cent., Fe 30·0 per cent., Sb 0·36 per cent., Pb 1·16 per cent., sulphur present, no Ag, Bi, Zn, Ni, Co.

(b) Chalcopyrite in quartz, from the ancient tip, Nantyrarian: Cu 13·14 per cent., Fe 14·83 per cent., Zn 18·78 per cent., Pb 0·6 per cent., Sb 0·04 per cent., Ni considerable traces, as traces, no Co, Ag, Bi.

(c) Chalcopyrite in quartz veins, Nantyricket, from the next tip to the ancient working at Lloches y Ladron, on the eastward continuation of the vein: Cu 20·89 per cent., Fe 24·31 per cent., Pb 0·51 per cent., sulphur present, Ag traces, as considerable traces, Sb, Bi, Zn, Ni, Co none.

(d) Impregnations of chalcopyrite and galena from the tips, Daren Fawr: Cu a little, Pb 0·8 per cent., Fe 4·26 per cent., Ni, Co, Zn, Sb, Ag, Bi none.

(e) Hard, heavy slag from Bryn Gefellau near Llanfihangel-Pennant (Caernarvon), received from Mr. Hemp; the slag is fairly well fused and looks very ferruginous, resembling bloomery slag: Fe 37·35 per cent., Zn 14·51 per cent., no Cu, Pb. It is difficult to decide whether this slag is derived from zinc-smelting or from iron-working with an ore which happened to contain much zinc; the temperature of bloomery slag would hardly be sufficient to volatilise zinc. It is hoped later to excavate the site.

(f) Black compact hillside slag, Mwyn-Bwll, apparently derived from a now denuded heap; the piece had been rolled and was rather flaky: Pb 9·74 per cent., Zn 10·21 per cent., Fe 11·51 per cent., no Bi, Cu. The position of the slag should date it to a period when zinc was very little sought, so it is probably derived from lead-working.

(g) Slag from a riverside site just east of Penrhyn-côch village, received from Mr. Jenan Williams through Mr. E. E. Evans. Not far off is an old leat. The site is near the sixteenth-century mine of Bryn Llwyd, and the situation suggests that it belongs to the early days of the revived mining industry. The specimens received were fused furnace-lining, made of impure gritty clay, showing a little lead on analysis; also fused stone. Pieces thought to be metallic slag have been found previously, some of which occluded a little lead ore.
BLOOD GROUPS.

Report of Committee on the Blood Grouping of Primitive Peoples (Prof. H. J. Fleure, F.R.S., Chairman; Prof. R. Ruggles Gates, F.R.S., Secretary; Prof. J. H. Hutton, C.I.E., Mr. R. U. Sayce).

During the past year over 400 natives have been tested at Kohima and Mokokchung in the Naga Hills, Assam, under the general direction of the Honorary Director of Ethnography, with serum supplied by the Haffkine Institute in Bombay. Many of these belong to the related tribes, Angamis, Lhotas, Semas and Rengmas. Many are Konyaks, while others belong to the Aos and the Thado Kuki. Significant differences in blood grouping already appear, and the work is being continued until larger numbers are available, in order to distinguish between the various tribes and groups tested. Mr. S. S. Sarkar, of the Bose Institute, Calcutta, is testing aboriginal tribes, the Mâle and Santal, in the Santal Perganas district of Bihar. Dr. Eileen W. Macfarlane has been continuing her blood grouping in India, combining it with anthropometric measurements. Two papers are in the press.

Serum was sent to the Canadian Government Expedition which spent the years 1934–36 studying the Eskimos in the area west of Hudson Bay. One hundred and twenty-six 'natives' were tested, but the results are not being published until fuller information can be obtained from another Expedition this year.

Nearly 300 Micmac Indians were tested with the help of Prof. Ralph Smith, Pathologist, Halifax, N.S. These included nearly 100 children from the Indian school at Shubenacadie, the remainder being mainly adults from two Indian reservations on Cape Breton Island. A paper on the Micmac Indians, who are even more mixed with white blood than the British Columbian Indians, is now in course of publication.

A satisfactory arrangement for blood grouping the Iroquois and Ojibway Indians of Canada has not yet been reached.

Prof. W. R. Morse, Dean of the College of Medicine in Chengtu, Western China, has succeeded in obtaining the blood groups of many Chwan Miao, as well as of 1,312 Szechwanese. A short paper on this subject is in the press.

A small pamphlet has been produced, pointing out the significance of the blood groups and the method by which they can be taken and recorded. This is available for distribution to local medical practitioners who may be interested and who reside in parts of the British Isles with pockets of population which may show peculiar blood group percentages combined with other physical differences. In this way it is hoped to initiate local blood group surveys in some of the more isolated parts of the country.
SCIENCE IN ADULT EDUCATION

Report of Committee appointed to consider and report on the place of Science in Adult Education (Dr. A. W. Pickard-Cambridge, Chairman; Mr. A. Gray Jones, Secretary; Mrs. V. Adams, Prof. W. B. Brierley, Prof. L. E. S. Eastham, Sir Richard Gregory, Bt., F.R.S., Mr. A. E. Henshall, Prof. R. Peers).

Contents.

1. Introduction.
2. Statistical Summary of Classes held under the Adult Education Regulations and under the Regulations for Further Education.
3. The Aims of Science Teaching in Adult Education.
4. Suggestions for the Teaching of various subjects.
5. Appendix. Specimen detailed Syllabuses and Bibliographies.

I. Introduction.

This report is necessarily brief and should be regarded as complementary to the interim report presented at the Leicester Meeting in 1933. That report was the work of an earlier Committee appointed at the York Meeting in 1932. The Committee comprehensively surveyed the position of science teaching in adult education and made a number of valuable suggestions and recommendations, but for various reasons was unable to complete the scheme of work proposed.

The present Committee was appointed at the Blackpool Meeting in 1936. They felt that in the light of experience gained since the issue of the 1933 Report, their terms of reference could most usefully be discharged by rapidly surveying the present position of science in adult classes, by defining the aims of science teaching and by presenting a series of agreed recommendations on the content of such teaching. Their work has thus to some extent proceeded on lines projected by the previous Committee.

The Report therefore opens with a statistical survey designed to show the number and percentages of adult educational classes studying one or other of the various branches of science. The statistics demonstrate the very modest position occupied by Science classes.

This is followed by a brief summary of the aims of science teaching in adult education, in which emphasis is laid on the social implications of science and its impact on the life of the community.

The next section provides a number of positive suggestions for the teaching of various scientific subjects. These take the form in each case of a brief summary of agreed opinion as to the general ground to be covered in (a) one year; (b) three year courses.

An appendix provides detailed syllabuses and bibliographies in biology, geology, and psychology, which may serve as examples.

The Committee trust that the topics suggested and the detailed syllabuses provided will be useful to all who are concerned to widen the field of science teaching in adult education. They believe that this can most fruitfully be done if the social implications of science are borne in mind. The relationship between science and the life of the community is emphasised in these suggestions, for the mature adult student becomes conscious of that relationship not only through his studies but also through his experience of life.

The following statistics of classes are compiled mainly from the Board of Education's Annual Report for 1935 (issued in October 1936). They show what subjects are taken in adult education classes recognised by the Board, under the Adult Education Regulations:

Classification of subjects other than those in Vacation Courses and Residential Colleges.

Year ended July 31, 1935.

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<table>
<thead>
<tr>
<th>Subject</th>
<th>Courses</th>
<th>Students in Attendance.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Men.</td>
</tr>
<tr>
<td>Literature and Language</td>
<td>95</td>
<td>591</td>
</tr>
<tr>
<td>Economics</td>
<td>34</td>
<td>592</td>
</tr>
<tr>
<td>History, General</td>
<td>38</td>
<td>358</td>
</tr>
<tr>
<td>History, Industrial</td>
<td>6</td>
<td>86</td>
</tr>
<tr>
<td>Geography</td>
<td>8</td>
<td>47</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>42</td>
<td>330</td>
</tr>
<tr>
<td>Natural Science</td>
<td>28</td>
<td>339</td>
</tr>
<tr>
<td>Sociology</td>
<td>62</td>
<td>737</td>
</tr>
<tr>
<td>Philosophy and Psychology</td>
<td>57</td>
<td>633</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>370</td>
<td>3,713</td>
</tr>
</tbody>
</table>

These figures indicate the lowly position held by Science classes.

Of the 783 Preparatory, Three Year and Advanced Tutorial Classes, only 55 or 7 per cent. are in natural science. Of the 1,359 One Year, Terminal and Short Terminal Courses, 154 or 11 per cent., and of the 370 University Extension Courses and Short University Extension Courses, 28 or 8 per cent. are in Natural Science.

A comparative table for the years 1933, 1934 and 1935 emphasises the fact that Science is not a popular subject.

<table>
<thead>
<tr>
<th>Year</th>
<th>Preparatory, Three Year and Advanced Tutorial</th>
<th>One Year, Terminal and Short Terminal</th>
<th>University Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>1933</td>
<td>(a) Total Classes</td>
<td>762</td>
<td>1,263</td>
</tr>
<tr>
<td></td>
<td>(b) Science</td>
<td>40</td>
<td>117</td>
</tr>
<tr>
<td>1934</td>
<td>(a) Total Classes</td>
<td>747</td>
<td>1,276</td>
</tr>
<tr>
<td></td>
<td>(b) Science</td>
<td>45</td>
<td>141</td>
</tr>
<tr>
<td>1935</td>
<td>(a) Total Classes</td>
<td>783</td>
<td>1,359</td>
</tr>
<tr>
<td></td>
<td>(b) Science</td>
<td>55</td>
<td>154</td>
</tr>
</tbody>
</table>

The Workers’ Educational Association, in their Annual Report for the year 1936, provide a subject analysis of their classes (Advanced Tutorial, Tutorial, Preparatory, One Year, Terminal, etc.) which shows that out of a total of 2,862 classes only 239 or 8.35 per cent. are in Science. These
totals naturally include most of the courses already enumerated in the Table quoted on p. 306.

An interesting point here is that the demand for Science classes varies as between one district and another, e.g.:

<table>
<thead>
<tr>
<th>District</th>
<th>Total Classes</th>
<th>Science</th>
<th>Per cent. of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern</td>
<td>113</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>North-East</td>
<td>234</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>South-East</td>
<td>94</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>West Lancs.</td>
<td>154</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>London</td>
<td>232</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>East Midlands</td>
<td>206</td>
<td>33</td>
<td>15</td>
</tr>
<tr>
<td>West Midlands</td>
<td>99</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Southern</td>
<td>64</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Berks, Bucks and Oxon</td>
<td>52</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>North Staffs.</td>
<td>41</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Western</td>
<td>145</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>North-Western</td>
<td>141</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>South-Western</td>
<td>157</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>North Yorks.</td>
<td>292</td>
<td>27</td>
<td>9</td>
</tr>
<tr>
<td>South Yorks.</td>
<td>227</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td>North Wales</td>
<td>154</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>South Wales</td>
<td>205</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Scotland</td>
<td>192</td>
<td>38</td>
<td>20</td>
</tr>
</tbody>
</table>

The comparatively high percentages in Scotland and the East Midlands are noteworthy, also the low percentages in London, South Wales, the South-East, and West Midland districts.

It may be of interest to note the classes in natural sciences at the evening institutes and colleges (i.e. classes for people engaged in some occupation in the daytime, who attend classes organised under schemes for technical or part-time education). These classes are conducted by Local Education Authorities under the Regulations for Further Education.

<table>
<thead>
<tr>
<th>Year</th>
<th>Evening Institutes</th>
<th>Evening Classes in Colleges</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>73,970</td>
</tr>
<tr>
<td></td>
<td>Natural Sci.</td>
<td>2,742</td>
</tr>
</tbody>
</table>

Expressed as percentages, these figures show that 4 per cent. of the classes (having 3 per cent. of the total students) are in natural sciences. The Science subjects taken are:
### 3. THE AIMS OF SCIENCE TEACHING IN ADULT EDUCATION.

The aims of science teaching in adult education may be briefly summarised as follows:

1. The study of science is a discipline which helps to develop a systematic, accurate and objective inquiry into ascertained facts. In this way powers of observation, criticism and diagnosis are promoted.

2. It is a cultural activity that broadens the student’s outlook and encourages him to seek an understanding of the fundamental facts of life. He is thus led to co-ordinate and synthesise his knowledge.

3. The use of scientific methods gives practice in clear thinking and impartial judgment.

4. The teaching of science provides knowledge likely to be of interest throughout life, by giving a wider meaning to personal experience and to the observation of natural phenomena, and a keener apprehension of the general principles underlying the structure of our material environment. In this sense a wise use of leisure is fostered.

5. A student will be led to recognise the part played by science and scientific achievement in moulding the society of to-day, and he will thus acquire a fuller understanding of human activity and of the manifold aspects of social development.

6. By apprehending the impact of science on the life of the community, a student will appreciate many of the forces that are continually re-shaping the fabric of our social life.

7. In realising the function of science as a co-operative enterprise of mankind, unhindered by racial or geographical frontiers, the student acquires a sense of social solidarity which should assist in the removal of barriers between nations and between different sections of society.

The Committee consider that there will be general agreement with this summary. Nevertheless they recognise that tutors and administrators
may be in some doubt as to the precise means whereby these aims can be achieved. The issue of a memorandum by the Board of Education (A.E.R. No. 7) in 1935 appears to have caused some confusion in this respect, although it does not appear that the Board have placed any obstacle in the way of any reasonable course in natural science for adult students.

The Committee consider that this memorandum was based upon a wrong conception of the scope and function of science teaching in adult education, in particular:

(1) Its insistence upon experimental work is too rigid, and fails to recognise the difference in the conditions governing adult education from those of academic work.

(2) Its partial condemnation of the historical method for the teaching of science is not justified by experience, which shows that a student can acquire a valuable degree of understanding even of an experimental science such as chemistry, through the skilled presentation of the history of the science.

(3) It underrates the social implications of science. In adult education it is necessary to begin at a point where the interest of the students can be secured. It is to a great extent in social history and conditions that they are interested, and the impact of science on the life of the community and of themselves is of fundamental importance and forms an excellent starting point for arousing interest in the study of science for its own sake.

(4) Adult classes do not, and in the Committee's view should not, view the study of science with the somewhat academic outlook that still obtains in the Universities and schools. To the adult student science should be a branch of human study associated more or less closely with human activities, since scientific achievement has a direct contact with social development.


The Committee realise that there will be a great diversity of opinion among tutors and organisers as to the manner in which a subject should be studied by adult classes. Equally there is considerable variation of views as to what should be the content of a course in a particular science. This will naturally vary with the type of student composing each class.

But with these reservations the Committee offer the following specimen suggestions (which cover only a few subjects) in the hope that they will be of service to those engaged in the teaching of science to adult classes.

*Anthropology and Geography.*

**One Year Courses.**

(a) *The Evolution of Civilisation.*—Man becomes man on grasslands and learns to walk erect, he becomes a hunter, woman remains a collector. The spread of desert over erstwhile grasslands through climatic changes following the passing away of the great ice sheets of the Pleistocene Ice Ages leads to concentration of population near rivers and springs and to care of plants (by the women) whence origins of cultivation in Egypt, Mesopotamia, etc. At first women's work, but later on domestication of animals brings in the men and the plough. Settled life near regularly flooding rivers leads to observation of stars and formation of a calendar, priesthoods, temples, markets, cities. Spread of civilisation into various regions may be outlined.
(b) *The Races of the Old World.*—Man learns to walk erect on the grasslands and improves stereoscopic vision. Woman increases material activities and duties (babies helpless till they can walk, a long process of learning). Spread of man (a) into equatorial Africa and consequent adaptations—the dark glistening skin with large sweat glands, the lips and nose; (b) into Central and East Central Asia, related features the dry yellow-brown skin with few pores and so on; (c) into Europe with neither of these lines of specialisation strongly marked, but a tendency to lose pigment.

Note remnants of ‘early’ groups of mankind in far corners—Bushmen of S.W. Africa, Australians, Tasmanians, etc., and in equatorial forests (Pigmies).

(c) *Society and Liberty.*—The routine of agriculture (see (a)) accompanied by Fertility Rituals. The conquest of one people by another, especially tillers by herdsmen. The co-existence of two strongly contrasted traditions side by side leads to comparisons and reflections and so to emancipation of some minds from domination by ritual. Rise of ‘prophets’ and ethical and philosophical teaching within a few centuries more or less independently in China, India, Iran, Israel and Greece.

(d) *The Nation.*—Emergence of a consciousness of kinship beyond the local community, importance of a common cradle language and a common ruler, influence of a common struggle against foes. S.E. England and France (Paris Basin) with easy communications, suitable for relatively rapid development of national idea with more centralisation, as time went on, in Paris, then to London. Reasons of both physical geography and tradition for later development in Germany and Italy.

(e) *What is a Peasantry?*—The local almost self-sufficing agricultural community and its more rapid transformation in the West. Land tenure and growth of individual property in land. Decline of homecrafts in the West. Greater persistence of homecrafts and peasant life in East Central Europe.

(f) *The Idea of the City.*—Origin in Mesopotamia and Egypt (see (a)). Transplantation of such a complex set of ideas necessarily slow. Reaches Aegean and India about 3000 B.C. and China perhaps a little later. Reaches W. Mediterranean after 1000 B.C. Gaul under the Romans, Germany East of Rhine, North of Danube in the Middle Ages—and so on. Transplantation made much more rapid and easy with rise of large ships and machinery.

(Note.—Most of these courses could be combined and expanded into three year courses, e.g. (a) and (b) could be interwoven and would make a three year course and could include discussion of the Jews and the Nordic Idea. (a), (c) and (e) could be interwoven as a study of agriculture leading on to a comparison especially of Intertropical Africa, India, China, Japan and Europe including U.S.S.R.

Portions of (a), (d), (e), (f) could be linked up in a study of the evolution of British Life with a class interested in archaeological work.

Portions of (d), (e), (f) could be expanded into a review of International Problems in Europe.

Another profitable line would be the Spread of European peoples over the New World (three year course), contrasting Spanish, Portuguese and Anglo-Saxon schemes and referring to the peoples of older standing in the Americas.

The Arctic Peoples; Social Hierarchies; Phases of Maritime Commerce; Features of International Trade especially connected with International capitalism, and so on, are all possibilities.)

Prof. H. J. Fleure.
Astronomy.

In a course of Astronomy intended to interest adult students it is suggested that more attention should be given to the reaction and application of astronomical observations in everyday life and thought than to descriptions of the nature and constitutions of celestial bodies. From the earliest days to the present time people have been impressed by what they see in the stellar heavens, and they can appreciate more easily such configurations and movements than they can understand clearly the significance of many discoveries made with the telescope or spectroscope.

The determination of cardinal points, and the use of observations of stars and of the sun to determine positions on the earth for navigational or other purposes were widely used long before anything was known about the constitutions of these bodies. It is desirable to realise that the knowledge of astronomical phenomena among adults generally, or the interest in it, is much the same as that of primitive observers. The intention should be, therefore, to revive this contact of mind with the heavens by showing how early observations and conclusions affected thought and action and how the human race has been influenced by knowledge, as shown not merely in direct applications but also in mythology, literature, and intellectual development. Among subjects which suggest themselves as suitable for inclusion in such a course of astronomy are the following:

- Early recognition of constellations or groups of bright stars.
- References by Homer and Hesiod to Orion, the Great Bear, and the Pleiades.
- Aratus's description of constellations.
- Ptolemy's forty-eight constellations described in his *Almagest*, still accepted by astronomers.
- Association of Greek mythology with names of constellations.
- Apparent annual movement of the sun among the stars.
- Division of the movement into twelve parts (the Zodiacal circle).
- Constellations and signs of the Zodiac.
- The Zodiac of Denderah (Egypt) and that of the Greeks.
- Identification of Egyptian gods with the twelve Zodiacal signs. Mention in the Book of Kings of worship of the twelve signs, along with the sun and moon.
- Recognition of Zodiacal signs in Jacob's blessing of his sons.
- Association of Zodiacal constellations with seasons.
- Egyptian observations of the Dog Star—Sirius—and connection between the rising of this star and the rising of the Nile.
- Orientation of solar temples in Egypt and of the Great Pyramids.
- Egyptian year of 360 days plus 5 additional days representing birthdays of the principal gods.
- Length of seasonal year, 365 days, 5 hours 45 minutes 46 secs. in Solar time.
- Construction of the Julian Calendar by the Egyptian astronomer, Sosigenes.
- The Gregorian Calendar and its adoption in Great Britain in 1752, by the omission of eleven days, September 3 being reckoned as September 14.
- Early ideas as to the shape and movements of the earth. Copernicus, Kepler and Galileo in relation to the substitution of the Copernican for the Ptolemaic conception of the universe. Human reluctance to accept the view that the earth is not the centre of celestial movements, so that the main principles of astrology are undermined.
- Newton's discovery of the law of gravitation, and its use in providing mechanical principles to interpret astronomical movements. Conjunctions
of planets, appearances of comets, and similar aspects of the sky now determined by a single law. Unnecessary to assume association of any such events with occurrences and people on the earth, such as visitations of plague, human iniquities, wars, etc. Sense of justice and civilising influence which resulted from a knowledge of the existence and permanence of law in Nature.

Intellectual expansion brought about by new knowledge of celestial bodies and the extent of the universe.

Eclipses of the sun and what they reveal. Solar prominences and the discovery of helium in them. Identification of helium on the earth and its use in airships, etc. Sunspots and the solar cycle, and their effect upon magnetic conditions and broadcasting. Relationship between the sunspot period and levels of lakes in Central Africa. Search for direct connection between solar conditions and terrestrial weather.

The Milky Way or Galaxy; Galileo’s observations of its character; Milton’s references to them.

The Milky Way interpreted as the girdle of the stellar system: Sir William Herschel’s conclusions as to the structure of this system. Modern views as to ‘island universes’ or stellar systems, represented by spiral nebulae, beyond the Milky Way.

Origin of the solar system. Laplace’s nebular hypothesis; Tennyson’s accurate references to it; objections to the theory and search by astronomers for a substitute for it. Great interest now shown by intelligent public in new conceptions of the nature and origin of the solar system and the stellar universe.

Sir Richard Gregory.

**Chemistry and Citizenship.**


*Food.*—Requirements of the body for energy and maintenance of tissues, proteins, fats, carbohydrates, salts, water, vitamins. Importance of special elements, e.g. iodine. Effects of cooking, refrigerating, canning, chemical preservatives.


*Rubber.*—Origin and properties. Vulcanisation. Direct manufacture from latex. Fillers and effect on strength, life, etc. Artificial rubber.

*Plastics.*—Discovery, manufacture, properties, uses, etc., of synthetic resins.


*Metals and Alloys.* (b) *Non-Ferrous.*—Copper, tin, brass, aluminium,
lead. Use and future. Possibilities, etc. of rarer metals, e.g. beryllium, vanadium. Processes such as soldering, galvanising, welding, etc.

Medicine.—Discovering the chemistry of the body. Various drugs and how they work. Anaesthetics—general and local. Antiseptics. Toilet goods and cosmetics.


Chemistry in Warfare.—Explosives, propellant and disruptive. Poison gas and gas-masks. Verey lights, etc. Incendiary bombs.

Our Wasting Assets.—The mineral stocks of the world—coal, oil, metal ores, phosphates. Synthetic substitutes to replace exhausted natural stocks.

Conclusion.—Good and bad effects of chemical development. Scientific method and mode of thought. Examples from chemistry and possible applications to citizenship, economic life, e.g. water, sewages, etc.

(This list of subjects is a comprehensive one from which a selection can be made suitable to the needs of the class-students and the industrial organisation of the district in which they live.)

J. Wickham Murray.
Dr. J. Seeley.

Mathematics.

One Year Extension Courses.
(i) Exact Sciences and their relation to logic and philosophy.
(ii) The Universe and its relation to human destiny.
(iii) History of Mathematics and relation to the origin, growth and diffusion of mathematical ideas to social, political and intellectual conditions.
(iv) Pioneers of Astronomy: Ptolemy, Copernicus, Kepler, Galileo, Newton, W. Herschel, Einstein.
(v) Mathematical Theory of Harmony, and its relation to music, etc.
(vi) Aeronautics: Airship and Aeroplane, and their influence on transport, international relations and geography, as e.g. affected by Soviet work in Arctic.
(vii) Mathematics and Mechanics of Games and Recreations.
(viii) Geometry and Physics: modern relativistic ideas.

Three Year Tutorial Courses.
(i) Statistics, with application to social problems (wages, population, unemployment, world trade, etc.)
(ii) Number: development of number concept and its relation to the expansion of human ideas in social life and in the natural sciences.
(iii) Mechanics: principles of statics, dynamics, hydrostatics and hydraulics, in application to simple mechanisms, elementary astronomy, aeronautics, etc.

Books.

See List of Books suitable for School Libraries, compiled by the Mathematical Association (Bell), 1936. 15.

and add

Mathematics for the Million, by L. Hogben (Allen and Unwin), 1937. 12s. 6d.
(A cheap edition is expected shortly).

Men of Mathematics, by E. T. Bell (Gollancz), 1937. 12s. 6d.

Profs. E. T. Piaggio and H. Brodetsky.
5. Appendix.

As explained in the Introduction and in Section 3, it was felt by the Committee that in addition to providing general suggestions for the teaching of scientific subjects, tutors might welcome some examples of detailed syllabuses with bibliographies.

Accordingly, these have been prepared with special reference to the needs of (a) one year courses, (b) three year courses, in Biology, Geology and Psychology.

**Biology.**

*Suggested Syllabus of a Course of Twenty-four Lectures on The Biological Sciences and Modern Problems.*

**A. Introduction.**

*Lecture I.*

*The Nature and Scope of the Biological Sciences.*

The nature of science; the development of science; the organisation and practice of research. The nature, scope and relationships of biology, psychology, anthropology, sociology. Ideals, viewpoints, criteria and values in biological research. The social and the personal equation. The philosophy of science and of biology. Limitations of science; where is science going? Modern problems.

References: 4, 11, 27, 35, 36, 39, 42, 56, 74, 79, 81, 82.

**B. Problems of Individual Life.**

*Lecture II.*

*Growth and Development.*


References: 11, 14, 17, 39, 63, 68, 78, 79.

**Lecture III.*

*Sex, Mating and Reproduction.*

The nature, origin and meaning of sex: sex and reproduction. Male and female; sex determination; the sex ratio; the development of sex organs and of secondary characters. Copulation and its significance. The place of sex in individual and social life: ideals and actualities, inhibitions, repressions and abnormal states. Problems originating in sex.

References: 2, 14, 17, 20, 21, 33, 35, 42, 47, 63, 64, 73, 79.

**Lecture IV.*

*Conception to Birth.*

The germ cells. Parthenogenesis; nature and significance of fertilisation; immediate and more remote consequences. Gestation; foetal development; the process of birth. The control of conception; sterilisation; abortion. Individual and social values; ideals and actualities. Research and possibilities of the future.

References: 14, 17, 21, 33, 51, 63, 64, 79.
Lecture V.

Old Age and Death.
The duration of life, Biological time. The process of ageing; bodily and mental changes, rejuvenescence. The process of dying; reversible and irreversible changes. The nature and significance of death. The disinintegration of the body. The cultivation of tissues in vitro; potential immortality. Research and possibilities of the future.

References: 11, 14, 20, 33, 63, 69, 79.

Lecture VI.

Body and Mind.

References: 2, 8, 10, 11, 14, 35, 42, 47, 62, 63, 67, 73, 79.

Lecture VII.

Biology and Religion.
Religion to-day; creeds and sects, ethics and morals. The nature of religion; the religious attitude to life; revelation and belief. The nature of science; the scientific attitude to life; experimentalism and doubt. Some modern scientists and religion. A biologist's position.

References: 1, 3, 4, 5, 8, 11, 14, 24, 25, 35, 36, 45, 47, 74, 79, 80, 81, 82.

C. Problems of Disease.

Lecture VIII.

The Individual Aspect.
The nature of health and disease in plants and animals. Diseased bodies and diseased minds. Kinds of disease; causes; immediate and remote consequences. Preventive and remedial measures; theory and practice. Human, animal and plant experiments. Ideals and problems of clinical research.

References: 2, 10, 11, 53, 63, 69, 73, 75, 79.

Lecture IX.

The Social Aspect.
Clinical medicine, epidemics and crowd diseases in plants and animals. The development of epidemiological science and the position to-day. The collection, classification and interpretation of data. Disease factors. Experimental research and some modern problems.

References: 11, 32, 53, 63, 75, 79.

Lecture X.

Special Problems (i).
Tuberculosis, venereal diseases, smallpox, cancer: consideration of the foregoing in their individual and social aspects. Some outstanding problems; modern research.

References: 7, 15, 32, 53, 63, 69, 75.
Lecture XI.

Special Problems (ii).

References: 1, 2, 7, 10, 11, 15, 35, 47, 53, 57, 63, 69, 73.

D. Problems of Race.

Lecture XII.

General Aspects and Problems.
The meaning of race. Race and nationality. Race and culture. Racial characteristics, aptitudes and values. The origin, development, distribution and stability of races. Race migration, mixture, segregation, survival and extinction. The general racial position in the world to-day and the problems at issue.

References: 6, 30, 34, 37, 38, 40, 41, 42, 46, 59, 61, 70, 79.

Lecture XIII.

Special Problems—African Races.

References: 34, 43, 49, 55, 71.

Lecture XIV.

Special Problems—Asiatic Races.
The races of Asia: white and brown, yellow origin, physical characters, general distribution. India, China, Japan: racial history and present constitution. Biological aspects of the cultural, social and political problems at issue. Retrospects and prospects.

References: 6, 18, 34, 50.

Lecture XV.

Special Problems—European Races.
The racial history and present constitution of the peoples of Europe. Aryans, Nordics, Jews. Race and culture; political and social problems; biological data. Retrospects and prospects.

References: 6, 22, 34, 37, 38, 41, 59, 70, 76.

Lecture XVI.

The Evolution of Man.

References: 6, 14, 19, 34, 44, 79.
E. Problems of Society.
Lecture XVII.

Population Problems.
References: 6, 12, 13, 40, 48.

Lecture XVIII.

Eugenics.
References: 7, 15, 16, 23, 40, 42, 51, 57, 60, 61, 69, 76.

Lecture XIX.

War and Peace.
References: 28, 29, 35, 54, 76.

Lecture XX.

Educational and Cultural Values.
The meaning of education and culture. The development and present state of world civilisation; factors of race, of disease, of science. Political, economic, cultural, and scientific history. Intelligence and character in individuals, classes, races. The idea of progress: biological and sociological values. Liberty, equality and fraternity. Conditions of a permanent civilisation and of a progressive one.
References: 1, 9, 11, 19, 23, 26, 27, 28, 30, 35, 37, 38, 40, 41, 46, 50, 51, 52, 38, 59, 69, 70, 74, 76, 79, 81, 82.

F. Problems of Food.
Lecture XXI.

Food Supplies.
References: 6, 12, 27, 31, 52, 63, 65, 66, 72, 77, 79.

Lecture XXII.

Transport and Storage of Food.
Food supply and distribution in relation to population densities and changes. Importance of transport and storage. The biological problems involved: modern achievements and research.
References: 12, 27, 31, 52, 56, 63, 65, 66, 72, 77, 79.
Menaces to the Food Supply.

References: 12, 27, 31, 56, 63, 65, 66, 72, 77, 79.

G. Conclusion.

Biology and Civilisation.
General commentary on the biological aspects of the relation of the individual to society and on social structure and functioning. The pace of progress and human adaptability; knowledge and wisdom. Biology and statecraft. The worlds of yesterday, to-day and to-morrow; actualities, probabilities, possibilities.

References: 1, 4, 6, 9, 11, 19, 23, 26, 27, 28, 29, 35, 50, 51, 52, 58, 74, 76, 79, 81, 82.

References.
9. Burns, C. Delisle: Modern Civilisation on Trial (1931).
21. —— The Psychology of Sex (1933).
27. Furnas, C. C.: The Next Hundred Years (1936).
29. —— War, Sadism and Pacifism (1933).
34. Haddon, A. C.: The Races of Man (1924).
41. Huxley, J., and Haddon, A. C.: We Europeans (1935).
44. Leakey, L. S. B.: Adam’s Ancestors (1934).
47. Lorand, S. (Edit.): Psychoanalysis To-day (1933).
64. Robson, J. M.: Recent Advances in Sex and Reproductive Physiology (1934).
68. —— The Interpretation of Development and Heredity (1930).
71. Shapera, I. (Edit.): Western Civilisation and the Natives of South Africa (1934).
81. —— Adventures of Ideas (1933).
82. —— Science and the Modern World (1926).

References to smaller books and to articles in journals will be given during the lectures.

Valuable adjuncts are the Encyclopaedia Britannica, a good Dictionary, a large scale Atlas and the Statesman’s Yearbook.

Prof. W. B. Brierley.
(Reading.)

BIOLOGY.

Three Year Course in Animal Biology.

The following suggestions for a course extending over three years fall conveniently into 3 sections.

1. The establishment of a sound basis in functional and comparative morphology.
2. Ecology, Heredity and Evolution.
3. The History of Man and the impacts of the subject on the affairs of man.
1. Animal architecture. The general organisation of a Vertebrate animal and comparison with an Invertebrate type to show Nature's ways for obtaining the same functional ends by different types of structure.
2. The functions of living matter.
3. An introduction to functional morphology in some easily demonstrable type, e.g. the Frog, as a basis to human physiology and hygiene.
   (a) The alimentary canal, digestion and ingestion.
   (b) Respiration, the mechanism of breathing and the physiology of internal respiration.
   (c) The circulatory system.
   (d) Excretion.
   (e) Conductivity, sensitivity, reaction to environmental change.
   (f) Harmonious working of the body as controlled by nerves and the ductless glands.
   (g) Growth and reproduction.
4. A review of the animal kingdom. Where facilities exist, as in the form of museums or collections, this can be made fairly comprehensive but reduced to a minimum where such helps are not available.
6. Heredity, Variation and Evolution.
   (a) Evidences for evolution.
   (b) Theories of evolution.
   (c) Mechanism of inheritance.
7. The History of Man. Prehistoric and existing races of man.
8. Economic Zoology. Production. The Scientific aspects of Fishery investigations, Animal Domestication and other animal industries, e.g. Silk, Lac and Honey.
9. Economic Zoology. Problems of destruction; Agricultural, Veterinary and Medical.

Animal Biology.

Course for 1 year, of twenty-four lectures.

The subjects suggested for the three year course will serve equally well here, but the academic aspects such as those relating to comparative morphology (review of the animal kingdom) and to evidences of evolution must be greatly curtailed.

Special emphasis should be put on the application of Biology to human affairs.

Literature List.

Books marked * are suitable for members of the class.

* Bourne: Comparative Anatomy of Animals.
* Brachet: Embryologie des Vertébrés.
* Brumpt: Précis de Parasitologie.
* Crew: Sex Determination.
* Darwin: Origin of Species.
REPORTS ON THE STATE OF SCIENCE, ETC.

Dawidoff: Embryologie des Invertébrés.
* De Beer: Growth.
* Ealand: Insects and Man.
* Elliott Smith: Human History.
* —— The Evolution of Man.
* Ford: Mendelism and Evolution.
* Goodrich: Animal Organisms.
* Graham Kerr: Evolution.
* Text Book of Embryology. (Vertebrates.)
* Gray: Experimental Cytology.
* Haldane, J. S.: The Philosophical Basis of Biology.
* Haldane and Huxley: Animal Biology.
* Herrick: Neurological Foundations of Behaviour.
* —— The Brains of Rats and Men.
* Huxley and De Beer: Experimental Embryology.
* Jenkinson: Vertebrate Embryology.
* Jennings: Genetics.
* Kruif: Microbe Hunters.
* Lankester: Science from an Easy Chair.
* —— Secrets of Earth and Sea.
* Lull: Organic Evolution.
* MacBride: Text Book of Embryology. (Invertebrates.)
* Meek: The Migrations of Fish.
* Newbiggin: Plant and Animal Geography.
* Parker and Haswell: Text Book of Zoology.
* —— The Material of Life.
* Patten and Cragg: Medical Entomology.
* Patten and Evans: Animals of Medical and Veterinary Importance.
* Punnett: Mendelism.
* Shipley: Life.
* Thomson: Biology for Everyman.
* —— Problems of Applied Entomology.
* Wardle and Buckle: Principles of Insect Control.
* Wells and Huxley: The Science of Life.
* Wilson: The Cell.
* Woodger: Elementary Morphology and Physiology.
* Wood Jones: Arboreal Man.
* —— Man's Place among the Mammals.

Prof. Eastham.
(Sheffield.)

GEOLOGY.

It may be assumed that most students attending an Adult Education course in Geology will have practically no previous knowledge of the subject. The syllabus must therefore be attractive but may be quite elementary: owing to its many contacts with everyday life it is not difficult to devise a syllabus which will meet the needs of such students. Although Geology is closely linked with other sciences it is possible for a student quite unacquainted with any other science to make good progress in it; moreover, as it is essentially an observational science, more work can be done than in almost any science without equipment or laboratory facilities. It is thus peculiarly suitable as a subject for adult students, and may be followed by classes working under conditions where other sciences could not be studied. The fact that much practical work can best be done in the field is also an
advantage in relation to some classes, where Saturday excursions are a popular feature. The use of photographs or of lantern illustrations is very desirable.

The arrangements of a syllabus, and particularly the starting-point, must depend mainly on the district in which the class is held. Where there are geological features for study in the district, these usually form the best introduction. Classes held in large towns may find their first interest in building materials, classes in mining areas in the products of the mines. In all cases the use of local examples (or of examples from local holiday resorts) to illustrate phenomena described is very helpful. In some areas the wider or more philosophical aspects of geology, such as problems of earth history and structure or of evolution, may prove the most attractive. For either a three year or a one year course similar topics would be suitable, but the matter would be treated in greater detail and with a tendency towards a more formal basis in a three year course.

Bearing in mind the points above noted, the sequence of topics may be arranged to suit the particular class. In some cases, a scheme based primarily on the Geology or Scenery of the area would be appropriate. The following topics, however, cover a more general introduction to Geology, such as could be covered in a one year course.

One Year Course of General Geology.

1. The Constitution of the earth, its crust and interior.
2. Drifting Continents: land bridges and the distribution of animals.
3. Rocks and minerals.
4. The occurrence of rocks.
5. Rocks and Soils: The work of the weather.
6. Rivers and valleys; waterfalls and flood plains.
7. Springs and underground water. Caves and limestone scenery.
9. Coast scenery.
10. Changes of sea level.
11. Sedimentary and Igneous rocks.
12. Volcanoes: the extinct volcanoes of Britain.
13. Earthquakes and the information they give us.
17. A geological Time Scale: the Age of the Earth.
18. The geological history of Britain: an outline of the main episodes.
19. The Scenery of Britain in relation to its structure and history.

In most areas a suitable syllabus for a three year course would include a similar range of subjects, but the topics receiving most emphasis in later years would depend on the locality or on the interests of the class. The following arrangement would probably be suitable in many places.

First Year.

1. General Introduction to minerals and rocks.
2. Physical Geology: weathering, rivers, ice, seas.
3. The development of land forms and the history of scenery.
4. Structural geology: the arrangement of the rocks.
5. Earth-movements: igneous activity; volcanoes.
Second Year.
1. Historical Geology: the geological time scale.
2. A broad summary of the geological history of Britain.
3. The main outlines of the history of life: an introduction to the study of fossils.
4. The geology and scenery of the area in more detail.

Third Year.
1. The study of rocks.
2. The uses of geology (or the relation of geology to human life). Coal, its history and mining. Petroleum. Ores, their occurrence and exploitation. Other minerals, their distribution and their relations to human development (flint, salt, gem stones, etc.). Building materials; their characteristics in different regions, and their influence on early architecture. Water supplies.

BIBLIOGRAPHY.

A. M. Davies: *Evolution and the Modern Critics.* Murby.
Lake and Rastall: *A Text Book of Geology.* Arnold.
J. E. Marr: *Scientific Study of Scenery.* Methuen.
S. J. Shand: *Earth Lore.* Murby.

— *Useful Aspects of Geology.* Murby.
H. H. Swinnerton: *Outlines of Palaeontology.* Arnold.
G. W. Tyrell: *Principles of Petrology.* Methuen.
The Handbooks on British Regional Geology. Geological Survey. Geological Survey Memoirs, especially those dealing with areas adjacent to that in which the class is held.

Some Contacts of Geology with Everyday life, etc.
1. Scenery and the characteristics of landscape.
2. Mining. Supplies of coal, metals, etc. Distribution of supplies and international trade and problems. Distribution of population in relation to mineral supplies.
5. Soils and relation to solid rocks; influence on agriculture.
6. Landslips, coast destruction, etc. Drainage.

Prof. Trueman.
(Bristol.)

PSYCHOLOGY.

First Year.
The Groundwork of Psychology.

We shall devote our first year of study to making an acquaintance with the broad groundwork of psychology—its functions and methods; and with the general background of animal mind. Since man is a part of living
nature, it is useful to know something of the modes of behaviour which he shares with other living things, before trying to understand his particular mental life. Having thus prepared ourselves, we shall then turn to certain fundamental aspects of human psychology which are open to experimental study, as a training in objective methods as well as for their intrinsic interest. The more specialised fields of child psychology, industrial psychology and social and political studies, can be taken up in the second and third years.

I. What Psychology Is and Does.

Psychology is the study of mental life and covers both the field of behaviour and the field of consciousness. The various schools and isms in psychology and the reasons for these; the limitations and values of each as method. Mental life is not co-extensive with conscious experience; evidence for the significance of the 'unconscious.'

What makes psychology a science is its methods, which in the broadest terms it shares with all other sciences. Its special problems and handicaps. Its place among the sciences; a branch of the study of life as a whole, biology. Man's place in nature. The particular sorts of biological fact which are the province of psychology.

The methods of Psychology: General Outline.—(a) Introspection; training in exact self-observation; its limits and difficulties; attempts to apply measurement. (b) Objective methods; the direct study of animal and human behaviour. Experiment, and its special precautions in psychology. Mental measurement; mathematical aids; the limitations and risks of 'objective' measurement. (c) Methods of studying the 'unconscious,' wishes, anxieties, phantasies; mental mechanisms.

II. Preparation for Study of the Human Mind.

The fundamental characteristics of living things; sensibility and response; the 'wish' as the source of action; characteristic patterns of response; innate forms; their relation to bodily structure and its evolution. The ends of action; nutrition and reproduction. The behaviour of the simpler animals; the protozoa, earthworm; insects and insect societies. Reflex action and purpose; instinct and intelligence.

The behaviour of the birds and mammals; what is instinct? Its relation to habit, to emotions and to adaptive behaviour.

III. Some Aspects of Mental Life in Human Beings.

Instinct in man; its greater fluidity and adaptiveness. The neural mechanism of feeling and action in man; comparison of the nervous systems of man and other animals. The capacity to learn from individual experience; retentiveness and the conditioned reflex. Habit, and its experimental study. Skill in work and play. The effects of pleasure and pain.

The perception of 'things'—what is a thing? Qualitative, temporal and spatial patterns; movement and perception. Colour vision, cutaneous sensation, smell, taste, hearing. Recognition. Perceptual intelligence and adaptiveness. Emotion and its relation to instinct; bodily changes in emotion; the measurement of emotion.

Images and the imagination; imaginal types; eidetic imagery. The experimental study of remembering and forgetting.

The measurement of intelligence; mental age, mental retardation, mental ratio. The distribution of intelligence. Individual and group tests; verbal and practical intelligence. Experimental studies of reasoning.
Books for Reading and Reference.

Allen: Pleasure and Instinct.
Ballard: Group Tests.
—— Mental Tests.
Board of Education: Psychological Tests of Educable Capacity.
Brierley (Isaacs): An Introduction to Psychology.
Burt: Mental and Scholastic Tests.
Cannon: Bodily Changes in Pain, Hunger, Fear and Rage.
Darwin: The Expression of Emotions in Man and Animals.
Drever: Instinct in Man.
EIS: Pleasure and Instinct.
Freud: Introductory Lectures on Psycho-Analysis.
Heath: How we Behave.
Isaacs: The Children We Teach.
—— Intellectual Growth in Young Children.
James: Psychology (Briefers Course).
Jennings: The Behaviour of the Lower Organisms.
Kohler: The Mentality of Apes.
McDougall: An Outline of Psychology.
Myers: An Introduction to Experimental Psychology.
Myers and Bartlett: A Text-book of Experimental Psychology.
Pear: Remembering and Forgetting.
—— Skill in Work and Play.
Sandiford: Educational Psychology.
Stern: Psychology of Early Childhood.
Stutsman: Mental Measurement of Pre-School Children.
Terman: The Measurement of Intelligence.
Thomson and Geddes: Evolution.
Watson: Psychology from the Standpoint of a Behaviourist.
Woodworth: Psychology: A Study of Mental Life.
Yerkes: The Great Apes.
Zuckerman: Social Life in Monkeys and Apes.

Second Year.
Social and Industrial Psychology.

I. Social Psychology.

1. The field of social psychology, how it differs from that of individual psychology; the notions of 'group mind,' 'mob mind,' 'collective consciousness,' etc., must be taken as mere figures of speech; the concrete reality is always a number of individual body-minds behaving to and upon each other; social relations exist only as characteristics of the behaviour of individuals.

II. The date of social psychology; an adequate social psychology can only be built upon a wide study of:

A. The facts of social life.
   (a) Social institutions, habits, customs, and ideals in our own society to-day (including folklore).
   (b) Social institutions, etc., in other societies, including the 'primitive'; comparative ethnology.
   (c) The history of civilisation, including the 'prehistoric.'
   (d) The comparative study of animal societies and animal behaviour.

B. The genetic psychology of individual members of societies.

III. The methods of social psychology: (a) the sociological, and (b) the genetic; values and limitations of each; a combination of the two the most fruitful.

IV. Some current methods of approach: (a) Behaviourism; (b) McDougall; (c) Freud.
Grounds, methods and validities compared.
V. Some selected aspects of modern social life.
1. The psychology of 'the crowd'; suggestion; fashion; rumour.
2. The psychology of the highly organised group; voluntary groups.
3. The formation of public opinion; (a) in peace-time; (b) in war-time.
4. Some aspects of political life; the party system; electioneering; political loyalties and political changes.
5. The psychology of the 'economic man'; economic values and motives; acquisitiveness, constructiveness, and power.
6. Conservatism; revolutionism; communism; philanthropy.
8. Inter-racial psychology; our relation with the 'backward' and 'coloured' people.

II. Industrial Psychology.
1. The history of scientific method in the psychology of industrial life; 'scientific' management, welfare work, as precursors of industrial psychology.
2. The 'will to work'; specific motives and incentives.
3. Work and rest; hours and distribution of work; rest pauses; output.
4. The study of movement, and problems of training, in relation to health and happiness; the problem of monotony.
5. General conditions of efficiency; work and environment.
6. The psychology of accidents.
7. Square pegs in round holes; vocational guidance and selection.
8. Social relations in industry.

Books for Reading and Reference.

Social Psychology.

Bartlett: Psychology and Primitive Culture.
Belloc and Chesterton: The Party System.
Catlin: The Science and Method of Politics.
Dewey: Psychology and Social Practice.
Drever: Instinct in Man.
Ellwood: An Introduction to Social Psychology.
Ferenczi and Others: Psycho-analysis and the War Neuroses.
Flugel: The Psycho-analytic Study of the Family.
Frazer: The Golden Bough (Abbreviated ed.).
Freud: The Ego and the Id.
—— The Future of an Illusion.
—— Group Psychology and the Analysis of the Ego.
—— Introductory Lectures on Psycho-analysis.
—— Totem and Taboo.
—— Civilisation and its Discontents.
Ginsberg: The Psychology of Society.
Harrison: Ancient Art and Ritual.
Jones: Essays in Applied Psycho-analysis.
Laski: Authority in the Modern State.
—— A Grammar of Politics.
Le Bon: The Crowd.
Levy-Bruhl: Primitive Mentality.
—— How Natives Think.
Lippmann: Public Opinion.
—— A Preface to Morals.
—— Sex and Repression in Savage Society.
Marett: Psychology and Folk-lore.
A. The General Problem.

(a) What adolescence is; the biological facts; re-awakening and transformation of the sex impulse; internal secretions and secondary sexual characters; differentiation between the sexes in mind and body.

(b) The limit of growth in intelligence and the beginning of growth in specialised interests and organised knowledge; individual divergences of character and of interests.

(c) Changes in the family situation and in social needs: emotional development; regression to infantility; auto-erotism; the role of phantasy: the new 'object loves.' Hero worship and idealism; appeal of nature and art; play; dawn of true social spirit; changes in the attitude to authority.

(d) Possible solutions of the inner conflicts of adolescence:
In slow normal adaptation to reality by sublimation and intellectual freedom. The necessary conditions of this adaptation in relation to
(a) Economic life: the problem of vocational guidance.
(b) Social life, leisure and recreation; the adolescent’s need of romance, adventure, art and free social intercourse.

Practical considerations.
(2) In withdrawal from reality—the psycho-neuroses and their mechanisms.
(3) In outer defiance—the ‘runaway tendency’; juvenile faults and delinquencies.
(4) In religious experience—the psychological meaning of ‘conversion.’

B. Special Problems of Adolescence.
(1) The psychology of the criminal and of the juvenile delinquent.
(a) The adult criminal. Methods of individual study; Lombroso’s pioneer work; modern psychological technique; mental tests of level of intelligence and of special abilities; sensory and motor functions, memory, judgment, languages, etc.; the analysis of mental conflicts and repressions; psychic defects and aberrations. Correlations with frequency of anatomical and physiological peculiarities; medical data. Is there a ‘criminal type’? The relation between criminality and alcoholism, insanity, epilepsy, mental deficiency and other nervous disorders.

The characteristics of the ‘instinctive criminal’ psycho-analysis and ‘moral imbecility.’ Criminal art, language and literature. The problem of the recidivist is mainly one of education, and starts from the abnormal psychology of adolescence. The urgent need for psychological treatment of first offenders and probationers, and for psychological training of all who deal with juvenile delinquents.

(b) The young delinquent. The many factors involved; methods of psychological and social study; hereditary conditions; the home; poverty and defective family relationships; social life; companionships, leisure and work; physical factors of development and disease; intellectual factors: mental deficiency, dulness and super-normal ability; emotional factors and neuroses; methods of treatment and re-education; Juvenile Courts; the probation system; Home Office schools and Borstal.

(2) The psychology of religious experiences.

This special problem deserves to be taken up in detail and considered from a wider angle.

II. The Psychology of Religion.

What is the fundamental nature of religion, psychologically considered? There is no evidence of a ‘religious instinct’ nor a ‘religious sense.’ Discussion of the following views:

(a) Religion is thought, about the Infinite and Absolute (Spencer).
(b) Neither thinking nor acting, but intuition and feeling; a feeling of absolute dependence upon God (Schleiermacher).
(c) It involves both thought and feeling in a mode of behaviour, a practical relation with spiritual powers (Leuba).
(d) A valutational attitude (King).
(e) A desire to get into touch with and absorb the power of the final mysteries (Marett).
(f) At the least, a belief in spiritual beings (Tylor).
Rite as the expression in time and circumstance, belief as rationalisation, and feeling as the central core of the religious consciousness. The distinction between magic and religion in mental attitude and practice; bad (i.e. anti-social) v. good (i.e. social) ways of dealing with the unknown; impersonal v. personal conceptions; coercive v. propitiatory behaviour; self-assertive and self-subjective attitudes. The origins of magic and religion; the overflowing of pent-up emotion and desire into representation of what is desired; sympathetic magic; art and ritual. The inwardness of taboo; the influence of the great crises of life. The multiple source of the belief in unseen beings, personal and impersonal. The evolution of divine characteristics. The meaning of sacrifice; the scapegoat.

The lingerings of magic in the civilised; superstition, luck and charm.

The present facts of the religious life; blending of negative self-feeling, wonder, fear and tender emotion into awe and reverence. Saintliness, mysticism and asceticism.

The phenomena of conversion and its significance as a developmental crisis; the conflict between the instinctive man and the higher moral vision comes to a head; the 'sense of sin'; the 'surrender' as a ripening of the higher psychic functionings, the personal laying hold of the larger significances (God, Humanity, Goodness); there may be steady growth with little mark of crisis. Religious revivals. The relation between religion and morality. The reality of the sense of guilt as a permanent human problem.

Books for Reading and Reference.

Section I.

Addams: The Spirit of Youth and the City Streets.
Board of Education Consultative Committee Report: The Education of the Adolescent.
Blanchard: The Care of the Adolescent Child.
Bray: The Town Child.
— Boy Labour and Apprenticeship.
Brooks: The Psychology of Adolescence.
Burt: The Young Delinquent.
Dewey: Schools of Tomorrow.
— New Schools for Old.
Ellis: The Criminal.
Flugel: The Psycho-analytic Study of the Family.
Freeman: Boy Life and Labour.
Freud: The Ego and the Id.
— Group Psychology and the Analysis of the Ego.
Hadfield: Psychology and Morals.
Hall: Adolescence.
— Youth.
Howard: The Mixed School.
Healy: The Individual Delinquent.
— Pathological Lying, Accusation and Swindling.
Hoare: The Schools and Social Reform.
Hollingworth: The Psychology of Sub-normal Children.
Holmes: Psychology and Crime.
Lane: Talks to Parents and Teachers.
MacCurdy: Psychology of Emotion.
McDougall: The Group Mind.
— An Introduction to Social Psychology.
Morrison: Crime and its Causes.

The Mental life of the adult. The modes of experience.

The relation of perceiving to imagining. Kinds of mental imagery. Their relation to 'styles' of expression in speech and writing. Eidetic imagery. The rôle of imagery in thinking.


Speaking. Its functions. Its social significance and present-day importance. Its relation to problems of personality.

Dreaming and sleep. Likenesses and differences between waking and sleeping life.

Personality. Temperament and character.

Schools of psychology. The Gestalt School. The psycho-analysts. The Behaviourists. The factor school.

Modern theories of the motivation of conduct. The problems of adjustment to actuality. 'Minor' disabilities; popularly called shyness, clumsiness, laziness, stupidity.

'Type' psychology.

Applications of psychology to education, industry and medicine.

**Third Year. Psychological Aspects of Society.**


Prof. T. H. Pear.

(Manchester.)
SECTIONAL TRANSACTIONS.

SECTION A.
MATHEMATICAL AND PHYSICAL SCIENCES.

Thursday, September 2.

Symposium on X-ray methods and industry (10.0).

Sir William Bragg, O.M., K.B.E., Pres.R.S.—The application of X-ray methods to industry.

The X-rays supply new methods of examining the structure of a solid material. As a result we obtain details of the mutual arrangements of the atoms and molecules forming the design, and, in particular, we prove the existence of any of the regularity of arrangement which constitutes crystalinity. These matters are of importance to industry, since the properties of all materials depend ultimately on molecular arrangement. The X-ray methods have a number of useful features. They do not, for example, disrupt the specimen; they are content with minute amounts of material; they analyse in terms of molecules as well as of atoms and so on. On the other hand, the minute dimensions of themselves and of the details which they reveal are so widely separated from the dimensions of ordinary practice that it takes time to make connection between them, and as a consequence of their fundamental nature their application to industry is rather by way of their effect on industrial science than, at present, on workshop practice. The latter use is however considerable and the former is very great.

Dr. G. Shearer.—X-rays and the metal industry (10.20).

The use of X-ray diffraction methods in the study of metals provides a variety of information much of which cannot readily be obtained by other methods. Such studies give directly the arrangement of the atoms in the metal and show how this arrangement alters when, for example, other constituents are added to a pure metal to form an alloy. Less fundamental in nature but, at times, of more immediate application to industrial purposes, is the further information which such examinations yield. By means of X-rays it is possible to trace the effects on the structure of such processes as heat treatment, cold working, hardening and the like. The size, the state of perfection and the distribution in direction of its crystallites all have an important bearing on the properties of a metal, and by giving information on these aspects, X-rays extend the knowledge derived from studies with the microscope and help towards an understanding of the magnetic, electrical and tensile properties of the metal.
Dr. J. D. Bernal, F.R.S.—*X-rays and the food and chemical industries* (10.40).

The range of methods based on X-ray crystal diffraction have only begun to be used in the chemical industry, and it is not nearly well enough realised what possibilities they offer. So far, most work has been done in the use of X-rays as an auxiliary in the analysis of complex compounds, particularly natural products, vitamins, hormones, etc., and there they have shown that as an auxiliary method they are capable of shortening the ordinary chemical work by a very large factor. Their immediate practical utility may, however, be even greater.

X-rays provide an ideal method for standardising chemical products at all stages of manufacture and they are more sensitive than chemical analysis in that they detect differences of texture and body.

Their value in applied chemistry has been shown by their elucidation of the problem of bleaching powder which had baffled chemists for a century.

It can safely be claimed that the use of X-ray methods is likely to be equivalent in value to the chemical industry to such techniques as electrochemical analysis.

Mr. J. T. Randall and Mr. H. P. Rooksby.—*X-rays and the electrical industry* (11.5).

Although it is impossible to describe all the applications of X-rays which have been of value in the electrical industry, the following items have been chosen from recent investigations of interest.

Fluorescent materials are now of considerable importance in connection with colour modification of discharge lamps and television, and in our first example we show how the colour of fluorescence depends in certain instances on the crystal structure, and how, when solid solutions are possible, the colour of fluorescence may vary in a continuous way with the lattice constant. Specks of dirt hardly visible to the eye sometimes produce large fluorescent discolorations, and the specks may be identified by X-rays.

Another example is taken from metallurgy. When molybdenum sheet is successively rolled in two directions at right angles, after annealing characteristic fractures occur at 45° to the directions of rolling; the reasons for this can be understood from a study of X-ray orientation diagrams.

It is now well known that the differences between amorphous carbon and graphite are ones of degree, and this has led us to some interesting distinctions between the X-ray photographs of natural and artificial graphite. Some of the reflections observed by Finch in electron-diffraction photographs have been shown to appear in X-ray patterns of certain natural graphites, while these lines do not appear for any artificial graphite.

Dr. A. J. Bradley.—*X-rays and the permanent magnet industry* (11.40).

Powerful permanent magnets are made of alloys with a composition near to that of Fe₂NiAl. Their properties can be explained by X-rays. Powder photographs of slowly cooled Fe-Ni-Al alloys have given an entirely new phase diagram with many surprising features. The main single-phase areas are face-centred cubic ($\alpha$) and body-centred cubic ($\beta$). It was formerly thought that the intermediate area was simply an ($\alpha + \beta$) region, but this is only correct at high temperatures. On cooling the alloy, the receding $\beta$ boundary leaves a new two-phase area consisting entirely of body-centred
cubic crystals with different compositions. This is possible because the $\beta$ boundary on the nickel-rich side is curved like a bow. The two-phase $(\beta + \beta_2)$ area, between the bow and the bowstring, includes the composition Fe$_2$NiAl. On slow cooling, this alloy splits up into Fe$_{98}$NiAl ($\beta$) and Fe$_6$Ni$_2$Al$_7$ ($\beta_2$), with lattice dimensions differing by 0.3 per cent.

To develop maximum coercivity, the alloy is cooled at such a rate that there is not time to form two distinct types of crystal, but there is a continuous variation of composition. Tiny 'islands' of iron-rich material are forced to conform to the dimensions of the parent lattice. The resulting strain produces a powerful coercive force.

Mr. R. W. Powell and Mr. W. A. Wood.—Recent work on mica: thermal and X-ray (12.0).

(1) A description is given of an adaptation of the divided bar method for determinations of thermal conductivities of insulating materials at elevated temperatures, and of its application to the effect of temperatures up to 600° C. on the thermal conductivity of mica normal to the cleavage plane. Certain micas of the phlogopite type are found to show a sudden decrease in thermal conductivity at about 200° C. with a partial recovery only on cooling. Other specimens are free from this anomaly.

(2) An X-ray investigation has been made of the variations exhibited by the structure of the same specimens during a temperature cycle of 16° C. to 400° C. It is found that the heat treatment may bring about a very marked mosaic formation without apparent change in external appearance; that such a structure is not final but may revert partially to the original state on cooling; and that a close parallelism exists between this effect and the abnormal fall in thermal conductivity.

(3) The combination of the thermal and X-ray work thus provides a specific illustration of a fruitful application of X-rays to the study of a material of industrial importance.

GENERAL DISCUSSION on X-rays and industry (12.15).

AFTERNOON.

Visit to Ericsson's Telephone Works, Beeston.

Friday, September 3.

PRESIDENTIAL ADDRESS by Dr. G. W. C. Kaye, O.B.E., on Noise and the nation. (Illustrated by experiments.)

Mr. E. R. Davies.—Some recent discoveries on the action of light on photographic materials (11.30).

The sensitive layer in photographic materials consists chiefly of microscopic crystals of silver halide embedded in gelatine. The effect of light is visible only when the exposure is prolonged, metallic silver being formed. Far smaller exposures produce latent images which may be developed—a process of chemical reduction, whereby sufficiently exposed crystals are reduced to silver. This is a type of trigger action since nearly all the energy is supplied chemically and subsequent to exposure. The optical density of the developed image changes with the illumination for constant exposure.
(product of illumination and time). For any material there is an optimum rate of reception of energy, which varies with the temperature. While the density increases with the exposure over a wide range, prolonged exposure causes it to decrease (the region of solarization). The crystals in a layer vary very much in sensitivity, which, in general, increases with their size. The sensitivity is also governed by the nature of the surrounding medium and by traces of foreign matter: of great importance is the adsorption of certain dyes to the crystal faces thereby extending the natural sensitivity of the silver halides from the Blue-Violet towards the Red and even into the Infra-Red.

Mr. S. O. Rawling.—Modern views of the action of developers in photography (11.50).

In making a photograph, development is necessary to make the latent image visible. The unit is the crystal of silver halide; the greater the exposure the greater the number of developable crystals. The sensitivity of a crystal is inversely proportional to the exposure necessary to bring it across the threshold of developability. After application of a developer to a crystal in an exposed plate a period of waiting ensues during which no apparent change occurs; then development begins at one or more points on the crystal and spreads rapidly until the whole crystal is blackened. Development centres are probably coincident with the units of the latent image, which are believed to be particles of silver. The size of a particle of silver probably determines whether or not it can initiate development. The critical size has been variously estimated to lie between two or three atoms of silver and some hundreds of atoms. Theories of developer action are divided between two concepts: reduction of silver salts in solution with subsequent deposition of silver on the latent image, and adsorption of the developing agent by the latent image with subsequent reduction of silver halide in the surface of the crystal.

Prof. N. F. Mott, F.R.S.—A theory of latent image formation (12.10).

Ultra-violet light is known to colour rock salt crystals. The colour is due to free electrons released by a kind of internal photoelectric effect, as may be shown experimentally. The primary action of the light on the silver halide grains in a photographic emulsion is similar; electrons are liberated which combine with the silver ions to form silver atoms. In the print-out process these silver atoms coagulate to form metallic silver; a detailed mechanism of this coagulation is proposed. On the assumption that the latent image is a submicroscopic speck of silver, it is possible on the basis of this mechanism to understand the reason for the breakdown of the reciprocity law and also for the effect of temperature on the sensitivity of photographic emulsions.

General Discussion on The mode of action of the photographic plate (12.30).

Afternoon.

Mr. H. G. Green.—George Green, the mathematical physicist (1793–1841) (2.30).

The figure outstanding from the group of men, able and interested in scientific matters and banded together through their association with the
Bromley House Subscription Library, Nottingham, is that of George Green, self-taught in the main until after the publication of the thesis by which he is most remembered. His father was first a baker in Nottingham and then a prosperous miller in the neighbouring hamlet of Sneinton. The son assisted his father in the business, but at the same time pursued his scientific interests, which must have been regarded with sympathy by the family as the top storey of the mill was used by him as a study. In 1828 the Essay on the Application of Mathematical Analysis to the Theories of Electricity and Magnetism, which introduced the famous theorem, was published privately in Nottingham by subscription. Although lost to the scientific world in general until re-discovered in dramatic fashion by Sir William Thomson (Lord Kelvin) in 1845, the paper at once attracted the notice of Sir Edward Ffrench Bromhead of Thurlby, near Nottingham, who communicated his next two papers to the Cambridge Philosophical Society. According to a brother-in-law, Green found his work as a miller irksome, and after his father’s death (1829) he disposed of the business though he still retained the property. He then prepared himself to enter Gonville and Caius College, Cambridge, which he did in 1833 under the recommendation of Sir Ffrench Bromhead, though he apparently kept an active practical interest in local affairs, as a George Green was appointed trustee to a Sneinton charity in 1839. Becoming Fourth Wrangler in 1837, he proceeded two years later to a college fellowship, but his health failing after a year, he returned to Sneinton and died in 1841.

Visit to Sneinton.

Monday, September 6.

Joint Symposium of Sections A, B, and I on Surface action in biology (10.0).

Chairman: Prof. J. C. Philip, O.B.E., F.R.S.

Dr. Irving Langmuir.—Visible adsorbed films in the field of biology.

Interference minima with built-up films of forty-seven monolayers of barium stearate on chromium are so sharp that an increment of thickness of 2Å can be seen. The surface of such a plate can be conditioned (for example by dipping in a thorium nitrate solution) so that it can adsorb many substances from aqueous solution. Proteins, bile acids, etc., give saturated adsorbed films of characteristic accurately measurable thickness. Antibodies can be adsorbed on antigens, hydrocarbons on bile acids, digitonin on monolayers of cholesterol, etc. Often alternating multilayers can be built up by adsorption or by deposition from the surface of water. Many valuable properties of these films can be measured; thickness, refractive index, solubility, volatility, contact angle against various liquids, adsorbing power for other substances, X-ray and electron diffraction patterns. Permeability can be measured by determining the effect of a solvent in removing material from underlying layers, or the penetration of liquids or vapours through monolayers into the voids of an underlying skeleton film. The monolayers can act as catalysts for reactions involving substances in solution, in detecting and identifying minute amounts of substances of biological interest and in throwing light on their structure.
Dr. Henry Eyring.—*Absolute rates of reaction of large molecules* (10.30).

Using the theory of absolute reaction rates it is possible to calculate the entropy, heat and free energy of activation. These quantities for proteins permit us to make statements regarding the nature and number of bonds broken to form the activated state for denaturation. That the effectiveness of a homogeneous or heterogeneous catalyst depends upon the way the reactants fit on to the catalyst molecules has long been clear, since this determines the free energy of activation. How different this can be for optical isomers is considered for a number of cases. The experiments of Schwab, Rost and Rudolph show that \( \alpha \) secondary butyl alcohol is dehydrated faster on dextro quartz. This provides an interesting proof that the structural feature responsible for optical activity of the quartz in bulk is still preserved in the surface. This is important since it is much easier to study matter in bulk. From the structure of quartz and butyl alcohol the activated state is adduced and used by Condon, Altar and the present author to give the relative configuration of the quartz and alcohol. From the work of Hylleraas and a new theoretical treatment of optical activity by the above authors an assignment of the absolute configuration of quartz is then made. This leads to an assignment of the absolute configuration of all substances which can be related to butyl alcohol. While certain of the steps in the argument cannot be made with complete finality a new approach to the problem of absolute configurations is provided.

Prof. H. S. Taylor, F.R.S.—*Activation of specific bonds on surfaces* (11.10).

Prof. E. K. Rideal, M.B.E., F.R.S.—*Film reactions as biological models* (11.40).

**DISCUSSION** (12.10).

**AFTERNOON.**

**JOINT SYMPOSIUM on Surface action in biology (continued).**

Dr. J. F. Danielli.—*Permeability of cells* (2.30).

Dr. H. J. Phelps.—*The specificity of the reactions of the living cell* (3.0).

The recent extensions of our knowledge of interface phenomena have made it possible to speculate as to the structure of the surfaces of living cells. Biological reactions may be considered in two classes: reactions functionally affecting groups of cells which are not generally chemically very specific and those characteristic of individual cell metabolism which are often extremely specific. The great chemical specificity of the processes of metabolism have led to the view that at least some of the interfaces of, or within, the cell must be regarded as semi-rigid mosaics of great complexity. Such a theory must, however, be very incomplete. Not only are the chemical processes of the cell frequently highly specific but they are also 'thermodynamically very improbable' reactions. Consideration of the energetics of such reactions shows that living matter must possess the power of integrating the energy received by the normal impacts of molecular heat movements. If we consider the *probable* behaviour of large molecules anchored
in a rigid surface from the point of view of the quantum theory we may form a rough picture of the manner in which localisation of energy might take place. We must also take account of the very low molecular concentrations of certain substances which will, none the less, influence profoundly the course of biological processes, which would seem to show that the living cell is also capable of what we may call 'integration of time.'

**Discussion (3.30).**

**Concurrently with above:**—

**Symposium on The upper atmosphere (10.0).**

Prof. D. Brunt.—*The upper air and its importance in meteorology.*

The rate of decrease of temperature with height in the atmosphere is on the average roughly the same in all latitudes and at all heights up to a limit known as the tropopause, of which the mean height varies from about 17 km. at the equator to about 6 km. at the poles. Above the tropopause is the stratosphere within which temperature varies little with height.

The differences in height of the tropopause in different pressure distributions are discussed, and the variations of wind and density with height are considered from the point of view of their bearing on stratosphere flight.

Methods of observation of temperature in the upper air are described briefly, the importance of obtaining the observations without delay, for use in weather forecasting, is emphasised, and the practical value of the observations discussed.

Dr. K. C. Lange.—*Comparison between Harvard radio-meteorographs and airplane meteorographs (10.30).*

Dr. F. Paneth.—*Chemical exploration of the upper atmosphere.*

**General Discussion on The upper atmosphere.**

The above discussion on *The upper atmosphere* was preceded by the release, by Prof. D. Brunt, of a sounding balloon carrying a Dines meteorograph, which was watched by a large number of members of the Association. The instrument was attached to the balloon by a Baker release, consisting of a small aneroid which could be adjusted to open a catch, and so release the instruments from the balloon at any desired height. The release was adjusted so as to liberate the instruments at a height of about 12 kilometres. The instruments fell about four miles east of Grantham, and were picked up, and returned in good condition, by Mr. E. B. Dove of Ropsley.

The record of the meteorograph shows that the balloon dropped the instruments from a height of 12.3 kilometres. There was a normal fall of temperature within the first half kilometre above the ground, with an increase of temperature of about 1°C. in the next half kilometre, while above this the temperature fell off steadily up to about 12 kilometres, after which there was no further fall, indicating that the balloon had then entered the stratosphere. The temperature was about 13°C. at the ground and -55°C. at 12 kilometres.
Mr. A. L. Whiteley.—**Photo-electric control in industry** (11.45).

A comparison is made between the photo-electric (emissive) cell and other available types of photo-sensitive device, showing the advantages of the forementioned as regards sensitivity, speed of response and stability of characteristics.

The standard types of photo-electric relay are briefly described. The usual form of relay functions solely to open or close an electric circuit according to the level of illumination on its photo-electric cell.

Applications to machine tools, textile, printing and allied industries, control of street lighting, etc., are illustrated.

Applications relying upon the high-speed response characteristics of the photo-electric cell are shown to be among the most important uses of the device. Relatively simple photo-electric control can respond to a light change lasting less than \( \frac{1}{1000} \) second.

A further useful property of the caesium type of photo-electric cell is its rapid increase in output when the temperature of the light source is raised. For instance: if the temperature of the radiating body is raised from 1700° F. to 1800° F, the output of the photo-electric cell is doubled. This is the basis of operation of the photo-electric pyrometer, which has a number of advantages over other temperature-measuring instruments.

The alleged disadvantages of vacuum tube type apparatus in industry are dealt with; experiences with this class of apparatus in service are briefly described.

Prof. J. A. Carroll.—**Modern eclipse observing** (12.10).

To obtain the information sought in modern eclipse observing, full perfection of the optical parts of the instruments used is required. Modern optical manufacture is able to provide parts capable of yielding the full theoretical resolving powers, but only under conditions of good thermal equilibrium. In the laboratory this is easily attained, but in the field large regular and irregular diurnal changes of temperature are experienced.

The expedition to Omsk attempted for the first time full thermostatic control of the observing instruments. Interferometer observations necessitate thermal control, but practically all instruments can benefit materially from it. The arrangements used are described, and the success attained demonstrated.

A brief description of the programme of observations, the particular instruments used and the results obtained on this occasion are given, and also some account of Dr. R. L. Waterfield’s observations of the Corona at Chios.

Dr. A. D. Thackeray.—**The spectrum of the extreme limb of the sun** (12.30).

The few seconds at the beginning and end of a total solar eclipse offer a unique opportunity of studying the spectrum of the extreme limb of the sun and watching the transition from the Fraunhofer absorption spectrum to the bright line spectrum of the chromosphere. Enhanced lines which are characteristic of high temperature in the laboratory are stronger in the chromosphere than in the Fraunhofer spectrum. This seemed to point to the curious conclusion that the upper layers of the sun were hotter than the lower layers until ionisation theory showed that the lower pressure in the upper atmosphere would produce much the same effect as high temperature.
Absorption lines are supposed to be produced by combined scattering and absorption, the former process being predominant in the upper layers and being responsible for the bright lines in the chromosphere. The behaviour of absorption lines at the extreme limb is not fully accounted for by current theory. Lines represented strongly in the flash spectrum can be seen bright over the edge of the photosphere; numerous absorption lines due to neutral metals can be detected at the extreme limb, but excitation potential is an untrustworthy guide to their strength. There is an unexplained shift to the red of the absorption lines relative to the chromospheric lines.

Dr. R. L. Waterfield.—Coronography (12.45). Read by Prof. W. H. McCrea.

Afternoon.
Visits to Stanton Ironworks; Bar-Lock Factory; Messrs. John Taylor & Co., Bell Founders, Loughborough; North Wilford Power Station.

Tuesday, September 7.

Dr. Ezer Griffiths, F.R.S., and Mr. J. H. Awbery.—The contributions of refrigeration to everyday life (10.0).

A review is given of some recent investigations at the National Physical Laboratory and elsewhere which may be regarded as contributing to the comfort and convenience of everyday life.

They include:
1. Work on basic engineering problems of refrigeration.
2. Investigations in hygrometry which find application in methods of ‘air-conditioning.
3. Study of materials for thermal insulation.

Film illustrating Industrial physics at the National Physical Laboratory (10.20).

Prof. L. F. Bates.—The magnetic properties of amalgams (11.10).

The results of an examination of the magnetic properties of dilute amalgams of metals with mercury, produced by electrolysis or by mechanical means, are described. The dependence of the magnetic susceptibility at room temperatures upon the concentration of the dissolved metal, and the variation with temperature of the susceptibility of particular amalgams are discussed. Experiments with iron amalgams are described.

Mr. A. Brookes.—Some gas-absorption problems during annealing of low carbon iron (11.25).

Modernisation of a particular heat treatment department, replacing the old coke-fired furnaces by electric furnaces having automatic control and inert gas annealing resulted in the magnetic properties of the low carbon iron being appreciably inferior to those given by the older methods, and,
with many batches of material, the mechanical strength was so much reduced that large quantities of parts were scrapped during the assembly stages.

Investigations conducted, involving raw materials, heating and cooling rates, different soaking times and maximum temperatures, machining conditions, etc., proved that the magnetic degradation was due to nitriding caused by free ammonia, order of 0·5 per cent., in the cracked ammonia inert atmosphere. A purifier in the gas track eliminated the trouble.

The high magnetic properties of pure ferrite desired, tend to encourage mechanical weakness by large grain structure and elimination of inter grain. Dry hydrogen inert atmosphere has no effect, but H-H₂O gas penetrates the iron, reduces the iron carbide cementing medium, lowers elongation, increases brittleness and leaves tensile strength almost unaffected. Marked effects in practice occurred below 0·03 per cent. Controlled carburising gas admitted into the H atmosphere to balance reducing and oxidising effects eliminated the trouble and allowed the recovery of spoiled parts.

Miss M. D. WALLER.—Chladni designs produced by means of solid carbon dioxide (11.45).

Loud notes may be produced from metal objects by touching them with solid carbon dioxide. (Report British Association, p. 314, 1932; Proc. Phys. Soc. 45, 101, 1933; Nature, 135, 475, 1935.) This new method of producing vibrations has now been used to make a large number of Chladni designs and also to study the resonances of bodies of irregular shape. The value of the method depends upon the fact that the solid carbon dioxide can be applied to any point of the surface and is very vigorous in its action. The frequencies of the vibrations excited lie between about 1,000 and 4,000 c.p.s.

Dr. H. A. STEVENSON.—The prevention of steamy shop windows (12.0).

A description is given of an experimental shop-window which was built to investigate methods for preventing steamy windows. The apparatus used and the method of experimental procedure are also described.

Various methods for preventing steamy shop-windows are discussed from the theoretical and from the practical aspect. The most practicable of these methods—ventilation with air from the street—was examined in detail.

Natural ventilation proved to be effective but difficulty was experienced in securing adequate ventilation in actual shop practice.

Fan ventilation was found to be entirely satisfactory. All the desirable features of natural ventilation can be attained together with additional advantages, such as a greater rate of ventilation and a greater flexibility in the construction of the ventilating system.

Prof. J. SATTERLY.—The recent development of everyday physics and its application to Canadian life (12.15).

Refrigeration.—Canada is so large that meats, vegetables, fruits, fish, have to be refrigerated for home transportation.

Owing to the long winter and backward spring, early vegetables and fruits are imported and refrigerated from the countries to the South. The housewife also needs a refrigerator both in winter and in summer. Use of 'dry
ice.’ Portable refrigerators in delivery vans. A large amount of insulation is now being installed to keep us cool in summer and to lessen the winter’s fuel bill. Air conditioning and automatic humidification are becoming popular. Trans-continental trains are air-conditioned.

Geology.—An increasing use is made of physical methods for the solution of problems in detection of icebergs. Ice in rivers closes navigation and delays the reopening. Ice choking the inlets of hydro-electric stations and the turbines. Ice does damage on power transmission lines and on the wings of aeroplanes.

Air-navigation and Radio.—The Northern Canadian Airlines carry much more freight than the air lines of any other country. This is due to the development of mining in the north country. For the same reasons radio broadcasting has proved a great boon, lessening the isolation experienced in more lonely spots and enabling medical advice and air transportation to be used in cases of severe illness.

Forest fires are reported by air and radio and then are fought by men carried into the fire areas.

General.—The Universities are waking up to the need of providing men for these physical services. Graduate courses in meteorology and geophysics are now provided by the Physics Department of the University of Toronto, and an honours course in biology and physics has been started to train biologists with a sufficient knowledge of physics to study the problems of refrigeration—a subject so very important in a large agricultural country like Canada, and becoming more important as time goes on.

Afternoon.

Prof. W. Davis.—*The physical properties of knitted fabrics* (2.30).

(1) Place of the knitted fabric in textiles.
(2) Trend towards lighter-weight clothing.
(3) Properties of thickness, weight and compressibility, instruments for measuring these. Bulk/weight index of fabrics.
(4) Principles of wear testing; abrasion tests on textiles; temperature of abrasion; apparatus used.
(5) Testing fabrics by bursting; machines used. Tensile strength and elongation of fibres; yarns and fabrics under controlled conditions of temperature and humidity; the temperature/humidity control chamber. Stress/strain diagrams for wool, cotton and rayon.
(6) Apparatus used for testing flexibility, air permeability and the measurement of lustre on fabrics.
(7) Use of the ultra-violet lamp in detecting fabric faults. Lamps used for estimating the colour fastness; standard whites.

Working demonstration of newest types of experimental apparatus.

Afternoon.

Visits to Messrs. Boots’ Works, Island Street, Nottingham; to L.M.S. Railway Research Station, Derby, and to Messrs. Rolls Royce Works, Derby.
Saturday, September 4.

**Discussion on The unification of algebra in schools (10.0).**

Prof. E. H. Neville.

Mr. T. A. A. Broadbent.—*The teaching of algebra in schools: an introductory survey of the present situation (10.10).*

Much recent research work, in geometry and in certain branches of mathematical physics, for example, has shown an increased reliance on algebra, and in particular on the axiomatic fundamentals of algebra. In elementary school teaching, the groundwork concerning negative numbers, complex numbers, and similar concepts, has been clarified. The main problem in school teaching of algebra at the moment appears to be: Can the school course in algebra be systematised and unified so as to present with the university course a coherent body of doctrine, while at the same time allowing a pupil who ceases to learn algebra at some stage of the school course to feel that he has acquired the main ideas of a field of knowledge rather than unrelated fragments of information?

Mr. G. L. Parsons.—*Elementary algebra (10.30).*

Mr. M. H. A. Newman.—*The course as seen from the University (11.10).*

Mr. W. J. Langford.—*The teaching of algebra: limitations and possibilities in the school (11.35).*

The School Certificate course and its effect on the teaching of algebra. Lack of completeness in the topics of elementary algebra.

New approach to the study of equations and series. The value of 'problems' as distinct from 'examples.'

The transition to the more rigorous needs of the sixth form course. Absence of opportunities for gaining technique.

Analysis or algebra as the fundamental aim of advanced work in schools. The effect of the Higher Certificate and Open Scholarship examinations. The rival claims of two groups of pupils. Possibility of reconciling these claims with its effect on the teaching of the subject.

Need for an early treatment of complex number theory.

Comments on some of the topics which receive little or no treatment in the school course.

**General Discussion (12.0).**

Tuesday, September 7.

**Discussion on The bearing of higher geometry on the school course (10.0).**

Prof. H. T. H. Piaggio.
Prof. E. H. Neville.—The influence of the University on school geometry (10.10).

In the anticipation of developments proper to a later stage, the balance between technical skill and general ideas has not always been well held in the school course. Sometimes, as in the case of the circular points, verbal dexterity is acquired in a field of which no rational account is given. Sometimes, as in the case of curvature, we are content with trivial exercises when we might have exciting glimpses into higher geometry. The problem should be considered in relation both to the potential specialist and to the boy whose mathematics is a small part of a general education.

Mr. H. G. Green.—Infinity in Euclidean geometry (10.30).

The term ‘line at infinity’ as a device to cover a case of failure in the conical projection from plane to plane.

Discussions on the line at infinity and distant points regarded as discussions of a line and points near it in a projected figure. Circular points.

The plane at infinity: properties of the conicoids developed from the quadrangle formed by the intersection of two conics.

Prof. W. H. McCrea.—The circular points and elementary geometry (11.0).

Elementary geometry in schools is metrical euclidean geometry. The ‘point at infinity’ on a line is defined to give convenient expression to consequences of Euclid’s parallel postulate. The points at infinity on all lines in the euclidean plane satisfy formally the collinearity conditions; so we get the ‘line at infinity.’

It is convenient to define the ‘orthogonal involution’ on the line at infinity. Then, for example, a necessary and sufficient condition for a conic to be a circle is that all pairs of this involution should be conjugate with respect to the conic.

We might proceed to note the analogy with the conjugate pairs of points on the radical axis of a coaxal system; these form an involution, and, if it possesses double points, all circles of the system pass through them. So we might choose to say that all circles in the plane pass through the imaginary double points of the orthogonal involution, and so define the ‘circular points.’ But it is better not to do this, the concept of imaginary elements being foreign to this geometry. Instead, we can continue to work with the orthogonal involution. Example: foci of a conic.

Prof. H. S. Ruse.—Differential geometry (11.35).

The theory of the curvature, etc., of plane curves is usually treated as a mere by-product of the calculus; but since it contains many of the essential ideas of the generalised differential geometry that forms the basis of relativity and other branches of modern physics, it is worthy of greater attention. The interest of beginners (especially those intending to specialise in mathematics at a university) might be stimulated by the use of vector methods and by a general account of how the formulæ of plane differential geometry extend naturally to the theory of curves and surfaces in higher space. Such ideas are by no means beyond the understanding of the average student.

General Discussion (12.0).
Mr. C. H. H. Franklin.—*Hypersolid concepts, and the completeness of objects and phenomena* (12.30).

To picture mentally the Completeness of Things requires a more elaborate geometry than that of three space as directly observed with the eyes; needing the three Cartesian axes of ordinary space and other axes representing time, mass or any other dimensions to be considered; all axes mutually at right angles.

Just as it is possible to represent a three dimensional object by a two dimensional sketch; so it should be possible to represent a four, five, or more dimensional experience in a two space drawing or three space model: the picturing being regularly distorted but with parallel lines drawn parallel much as in an oblique or isogonal sketch, or, in geometrical perspective, with angular distortion and vanishing parallels such as would be ordinarily used in artistic work or found in a photograph.

While any group of lines passing through a point may serve as Cartesian axes for drawing or modelling hyperspace figuring (as in drawing three space objects); isogonal relation between axes, possible for four, six and ten space modelling, and any dimensional drawing gives minimum distortion and tends to the best representation; but regular oblique projection may be essential or preferable for five space or higher dimensional modelling.

Preliminary to picturing hypersolidity, familiarity with simple four and higher space forms, only distorted by the usual perspective or oblique projection of ordinary experience, is helpful. Demonstration of some of these forms, drawn or modelled and also of some Cartesian axial models.

It is noted that the oblique projections of the hypercube series have envelopes in three space which introduce an infinite series of rhombic semiregular solids, which follow at regular intervals on the rhombic hexahedron, rhombic dodecahedron, and rhombic icosahedron, and have polar and equatorial symmetry.

**SECTION B.—CHEMISTRY.**

*Thursday, September 2.*

Symposium on *Some aspects of chemotherapy* (10.0).

Presidential Address by Dr. F. L. Pyman, F.R.S., on *Researches in chemotherapy*.

Prof. Dr. H. Hörllein.—*The chemotherapy of bacterial diseases* (11.0).

Ten years ago investigations began in the Elberfeld laboratories of the I-G Farbenindustrie on the chemotherapy of bacterial diseases. Patents were taken out for the substance now known as Prontosil in 1932. The early results were so encouraging that further experiments were carried out, but the first publication appeared only in February 1935. The action of Prontosil on experimental streptococcal infections in mice was found to be the property of a whole series of compounds characterised by substituents such as sulphonamide or certain other sulphur-containing groups. A soluble variety of Prontosil was next discovered, having in common with
the base one-half of each molecule—i.e. the sulphonamide group attached to the azo group in the para position. Other chemicals, apart from the azo-series, which carry the sulphonamide group in the para position were also investigated.

The discovery of a general remedy for streptococcal diseases soon aroused scientific interest throughout the world, and much literature has now been published, first from the German clinics, and subsequently from those in other parts of the world. French investigators were the first to make public the fact that para-amino-phenyl-sulphonamide possessed antistreptococcal action.

In England the Therapeutic Trials Committee was given a supply of Prontosil, and this was tested out by Dr. Colebrook and his collaborators in the study of puerperal fever. Long and Bliss in America, hearing of the results obtained by the above workers, began investigations on their own. The value of the preparation was soon realised in erysipelas, puerperal fever and septic throat. Recently indications of treatment in diseases other than streptococcal have come to the front, namely, in meningococcal, pneumococcal, gonococcal and gas-gangrene infections.

The originators of the Prontosil compounds, Domagk and his collaborators, have succeeded in obtaining three compounds under the name of Diseptal which are allied to Prontosil and which exert an antistreptococcal action as effective as that already available together with an increased efficacy on staphylococci, gonococci, gas-gangrene and possibly other organisms. Clinical work with these compounds has already been published.

The mode of action and excretion of sulphonamide preparations has been studied by many writers. Despite the suggestion that the action of the two more complicated Prontosil compounds is explicable on the basis of decomposition to p-amino-phenyl-sulphonamide, it appears that this is not the complete explanation.

It is difficult to say what the future of chemotherapy will lead to, but it is believed that the new compounds (e.g. Diseptal) may act effectively against organisms other than those already mentioned.

Sir Gilbert T. Morgan and Mr. Eric Walton.—New derivatives of p-arsanilic acid (11.45).

During the last few years a group of compounds of general formula I and with values of \( n \) ranging from 0 to 8

\[
\text{AsO}_3\text{H}_2
\]

\[
\text{NH.COO}_n[\text{CH}_2]_n\cdot\text{CONR}_1\text{R}_2
\]

has been prepared at the Chemical Research Laboratory, Teddington. These compounds were in general obtained by condensing p-arsanilic acid with a derivative of a dibasic acid, usually the ester-acid chloride, and converting the product into an amine according to the scheme:

\[
\text{AsO}_3\text{H}_2\cdot\text{C}_6\text{H}_4\text{NH}_2 + \text{ClO}_2\cdot(\text{CH}_2)\cdot\text{COOR} \rightarrow \text{AsO}_3\text{H}_2\cdot\text{C}_6\text{H}_4\text{NH.CO.}(\text{CH}_2)\cdot\text{COOR} \rightarrow \text{AsO}_3\text{H}_2\cdot\text{C}_6\text{H}_4\text{NH.CO.}(\text{CH}_2)\cdot\text{CONR}_1\text{R}_2
\]

Nearly all the sodium salts of these amides proved to be trypanocidally active in mice, and accordingly three of the most promising, namely sodium
malonaniloethlamide \( p \)-arsonate \( (I: n = 1 \); \( R_1 = H \); \( R_2 = \text{Et} \), sodium succinanilomethylamide \( p \)-arsonate \( (I: n = 2 \); \( R_1 = H \); \( R_2 = \text{Me} \), and sodium glutaranilodimethylamide \( p \)-arsonate \( (I: n = 3 \); \( R_1 = \text{Me} \); \( R_2 = \text{Me} \) were chosen for further trials on rabbits. Of these three compounds the succinyl derivative, now known as Neocryl, was eventually selected for clinical trial.

Prof. Warrington Yorke and collaborators in the Liverpool School of Tropical Medicine have reported favourably on the action of Neocryl in all stages of syphilis, and Lester, working in Nigeria, has also obtained good results in the treatment of sleeping sickness.

Neocryl is now being tested on a larger scale under the auspices of the Therapeutic Trials Committee, but it is still too early to give a final judgment on the value of the drug.

Dr. W. Kikuth.—Experimental chemotherapy of malaria.

The great successes in the chemotherapy of malaria which have been achieved within recent years are due to team-work by chemists and biologists. Earlier attempts to treat malaria more efficiently by chemical means failed because no suitable test existed. It was not until bird-malaria (Protoosoma preecox), which proved so useful in the elucidation of many malarial problems, had been adopted for biological tests that the chemotherapy of malaria received a fresh stimulus which led to the discovery of the first synthetic remedy for malaria, plasmoquine. In contrast to quinine, plasmoquine possesses the property of destroying the sexual forms of malaria; it is, however, almost ineffective against the asexual forms of the parasites. A further advance in the biological test was made by employing rice-finches infected with hemoproteus. Owing to this improvement it was possible to differentiate in the laboratory between the effect of plasmoquine and that of quinine, and to discover a preparation which acts in the same manner as quinine, viz. atebrin. Further refinement of the method of testing as regards its specificity will result in new progress in the therapy of malaria.

Prof. R. Robinson, F.R.S.

Afternoon.

Excursion to Boots Pure Drug Company, Ltd., Island Street, Nottingham.

Friday, September 3.

Symposium on Protein chemistry (10.0).

Prof. C. R. Harington, F.R.S.—The contribution of organic chemistry to the problem of protein structure.

The historical development of the peptide theory of protein structure is outlined and the main lines of experimental evidence upon which it is based are discussed.

The importance of peptide synthesis for the study of proteins is emphasised and the earlier methods are briefly reviewed. The recently developed carbobenzyloxy method of Bergmann is treated in detail and its applica-
tions are illustrated by an account of the synthesis of glutathione and of recent work on the introduction of additional amino-acid residues into protein molecules.

Attention is called to the important possibilities of constitutional work on proteins which have been opened up by the method of stepwise degradation recently introduced by Bergmann.

Brief reference is made to alternative theories of protein structure which have been advanced from time to time. It is concluded that the peptide theory alone has adequate experimental support, but it is pointed out that the peptide linkage is insufficient by itself to account for all the properties of proteins; the possibility of the occurrence of subsidiary linkages must be admitted and it appears certain that an orderly arrangement must exist within the protein molecule, satisfying definite spatial requirements.

It is suggested that further progress in the study of proteins will be most effectively made by the application of physical and biochemical methods, but that this application must be based on the foundation which has been laid and is being extended by organic chemistry.

Dr. K. LINDERSTRØM-LANG.—Proteolytic enzymes.

Dr. W. T. ASTBURY.—X-ray interpretation of protein structure.

Of the two broad sub-divisions of protein structure, the fibrous and the non-fibrous, X-ray investigation has of recent years offered a view that allows us to look at the stereochemical picture, not as two apparently unrelated halves, but as a single intelligible whole. All proteins are fibrous in the molecular sense, the structural unit being the polypeptide chain, and in those proteins which exist naturally as fibres the chains generally lie in groups parallel, or simply related, to the visible fibre-axis. They may be stereochemically fully extended, as in silk fibroin, or constricted into regular linear folds, as in the unstretched or α-forms of the hair protein keratin and the muscle protein myosin, and the basis of the remarkable long-range elasticity observed in such cases is simply the pulling-out or further folding of the normal molecular configuration. The ultra-centrifuge, X-rays, etc., agree in finding the molecules of the soluble, and often visibly crystalline, proteins to be by no means obviously fibrous, but rather massive 'globular' bodies. The solution of this paradox comes from the interpretation of the phenomenon of protein denaturation, which is found by X-rays always to result in the production of polypeptide chain-bundles which can then sometimes be drawn parallel, or 'spun,' to form macroscopic fibres structurally analogous, especially on stretching, to the native protein fibres. Denaturation is thus in general the breakdown of a specific folded configuration of polypeptide chains, and the structure of the 'globular' proteins is apparently a logical generalisation in two or three dimensions of the regular linear folds first demonstrated in the molecules of the fibrous proteins. The contraction of hair or muscle represents no other than an intermediate stage between the fully-extended configuration of silk fibroin and the multiple folds of the globular proteins.

The regularly periodic structure of the proteins revealed by X-rays, especially in such cases as feather keratin and the recently identified tobacco-mosaic virus, is now finding its counterpart in the realisation, through the analytical work of Bergmann and others, that there are certain clear-cut stoichiometric relations between the proportions of the constituent amino-acid residues.
Dr. D. M. Wrinch.—*Structure of 'globular' proteins.*

A number of facts relating to proteins suggest that the polypeptides in native proteins are in a folded state; accordingly all types of folding which are geometrically possible are being investigated systematically. The cyclol link =N—C(OH)= is one such possibility. It replaces Fischer's *peptide link* by *multiple peptide links* and his *polypeptides* by *cyclol molecules.* The Cyclol theory thus presents for consideration a two-dimensional atomic network which, it may be suggested, is the fundamental entity in the protein molecule.

This theory, originally devised to deal with protein films and laminate proteins, is found to imply the existence of closed space-enclosing structures, which, owing to geometrical exigencies, exist only in certain sizes. It thus predicts in general terms the body of facts relating to the globular proteins established by Svedberg and his collaborators and suggests that each molecular weight class connotes a certain arrangement of amino-acid residues, say a certain closed cyclol, or an association of a number of such structures. Of the closed cyclols so far constructed, the cyclol containing 288 residues has been suggested as the structure of the proteins belonging to the 36,000 molecular weight class (egg albumen, insulin, pepsin . . .). On the basis of this structure, it was predicted that the number of residues per molecule belonging to this class is 288. The number was subsequently put forward by Bergmann and Niemann, on the basis of chemical analysis, as being the number of residues in each molecule of egg albumen. It has also been found that this structure fits the X-ray data for insulin and pepsin.

Dr. A. Neuberger.—*Electrochemistry of proteins and amino-acids.*

One of the most important advances in the electrochemistry of amino acids and proteins is the *zwitterion* theory, which explains satisfactorily the physical properties such as solubilities, melting-points and Raman spectra of these polar compounds. The dissociation constants of amino-acids in relation to those of fatty acids, amines and amino-acid esters can be quantitatively interpreted on this basis and estimates of dipol moments of *zwitterions* can be obtained. For proteins a quantitative relationship can be shown to exist between content of multivalent amino-acids and acid and base-binding capacity. It is further possible to interpret the titration curves of proteins in terms of the chemical composition; the correctness of such an interpretation can be proved by producing chemical changes in the protein which cause corresponding shifts in the titration curves.

The isoelectric points of proteins depend also on the chemical composition of the proteins, and it is possible to separate chemically different proteins by making use of differences in the isoelectric points.

Mr. J. St. L. Philpot.—*Ultracentrifugal investigation of proteins.*

The paper is a summary of the work of Svedberg and his collaborators at Upsala. Size-distributions of dissolved protein particles have been studied by measuring the rates of sedimentation in a centrifugal field 300,000 times that of gravity, with the following results: (1) A native protein in solution is 'oligodisperse' (i.e. its particles have a strictly limited number of sizes), while inorganic colloids are 'polydisperse' (i.e. their particles have every possible size within a wide range). This justifies the term 'protein molecule.' (2) Many protein molecules are spherical or nearly so. (3) The molecular weights tend to be simple multiples of 18,000, just as the atomic weights of elements tend to be multiples of that
of hydrogen. (4) Slight changes in the solvent can cause reversible aggregation or dissociation (the protein remaining oligodisperse). More drastic, irreversible treatments may cause polydispersity, though others even more drastic may cause no change. The behaviour differs for each protein.

Such measurements may be used as evidence concerning structure, as a criterion of purity, for controlling preparative procedures, and possibly for diagnosis of disease.

In collaboration with F. J. Philpot, the sedimentation constant of xanthine oxidase has been determined, with the aid of methylene blue and iodate.

Afternoon.
Excursion to Boots Pure Drug Company, Ltd., Beeston.

Monday, September 6.

JOINT SYMPOSIUM with Sections A (q.v.) and I, on Surface action in biology (10.0).

Afternoon.
Excursion to Stanton Iron Works, Ltd.
Excursion to John Player & Sons, Ltd., Nottingham.

Tuesday, September 7.

SYMPOSIUM on Chemistry of building materials (10.0).

Dr. R. E. STRADLING, C.B., M.C.—Introduction.

Dr. F. M. LEA.—Some problems in the study of hydraulic cements (10.10).

The term 'hydraulic cements' is usually restricted to those cements which will set and remain permanent under water. In the time available it is necessary to limit the discussion to the most important of the hydraulic cements, Portland cement, together with a brief summary of the properties required in a hydraulic cement.

The present state of knowledge of the constitution of Portland cement and the relation to the constitution of the properties which are of the most importance in practice, are briefly reviewed and attention drawn to points where knowledge is still lacking. Mention is made of the attack on concrete by ground waters containing sulphate salts and by soft mountain waters. The hydration of Portland cement is considered, leading up to a discussion of the structure of set cement. Certain physical properties of set cements, in particular changes in volume with moisture content and creep, or plastic flow under load, are mentioned and the theory of these discussed.

Dr. J. S. DUNN.—Calcium sulphate plasters: setting, retarders and accelerators (10.50).

Only three distinct crystal forms of calcium sulphate have been fully authenticated. It is unlikely that the elaborate series postulated by Davies has any
real existence. For various reasons hemihydrate is probably \(3\text{CaSO}_4\cdot2\text{H}_2\text{O}\), which it is proposed to call sub-hydrate. From a study of the solubility curves, sub-hydrate below 98° C. and anhydrite below 38° C. can take up water to form gypsum, and both should be capable of functioning as plasters at normal temperatures. Setting is a simple recrystallisation process, and it is not necessary to assume colloidal phenomena. The setting of sub-hydrate plasters in mixes of plastering consistency follows the law

\[
\frac{dx}{dt} = Kx(a - x).
\]

In dilute slurries, accelerated anhydrite plasters follow the law

\[
\frac{dx}{dt} = K(a - x).
\]

In mixes of plastering consistency, anhydrite plasters follow no simple law.

Retarders fall into two classes. One appears to work through adsorption on crystal faces. The other modifies the solubility relationships. In retarders, the anion is apparently the deciding factor.

Accelerators actually speed up the crystal growth of gypsum, although the mechanism of this action is obscure. There is a very rough analogy with the coagulation of sols in colloidal phenomena. It is possible that accelerators function through the removal or discharge of a protective layer on a growing crystal.

Mr. F. H. Clews, Mr. H. H. Macey and Dr. G. R. Rigby.—Some important properties of clay (11.30).

Problems arise in the manufacture of clay products from the nature and properties of the clay itself. Some of these problems are reviewed in the order of stages of treatment of the clay.

The natural deposits fall into different types and are used for different industrial purposes. Many of the essential minerals have been identified; investigations have been made into their atomic structure, and some have been synthesised.

The plasticity of clay is important. Reference is made to problems of measurement of plasticity and of the de-airing of plastic clay masses.

Clay shrinks on drying and strains are then inevitably produced. Problems therefore arise associated with the maximum safe rate of drying of masses of different shapes and dimensions. The mechanism of drying is discussed with special reference to recent work on the permeability of plastic clay.

The action of heat on clay during the firing of products brings about thermal decomposition of the clay minerals and other chemical changes, as for example, changes in soluble salt content, of interest in building products manufacture. Physical changes, such as changes in volume, specific gravity, colour, amount and character of pores, also occur and are technically important.

Dr. D. G. R. Bonnell.—Some problems connected with porous building materials (12.10).

The fact that many building materials are porous bodies gives rise to a number of problems which have to be studied if the materials are to be used to the best advantage by the building industry.

A brief summary is given of the behaviour of water in capillary spaces, and the relation between such behaviour and the properties of building materials is illustrated by:

(a) The influence of the pore structure on the frost resistance. In this connection mention is made of the important factors which must be
considered when an estimate of the frost resistance of a specified material is required.

(b) The conditions which induce crystallisation of salts on or under the surface of a porous body.

(c) The volume changes which take place during the wetting and drying of building materials.

SECTION C.—GEOLOGY.

Thursday, September 2.

Excursion preceding the meeting (August 27—September 1).

A Geological Excursion in the Tewkesbury area was held with the object of studying the Pleistocene Geology of the Lower Severn and Avon Valleys, under the direction of Prof. L. J. Wills and Miss M. E. Tomlinson. The River Terraces of the Severn between Holt (north of Worcester) and Arlingham (south of Gloucester) and of the Avon near Evesham were examined and discussed. A visit was also paid to the glacial deposits of the Ridgway, south of Redditch. A day was spent on the Frome Valley gravels under the direction of Mr. C. I. Gardiner, who also gave a demonstration in Stroud Museum of mammalian remains obtained from these gravels, and of reptilian bones recently obtained from the Oölite near Stow-in-the-Wold, Glos.

Mrs. E. M. Clifford conducted the party round the Barnwood gravel pits near Gloucester, and entertained the members to tea at her home at Witcombe, where a large and interesting collection of mammalian and archaeological remains which she had obtained from the Barnwood gravels were examined.

The geology of the Nottingham district.

Prof. H. H. Swinnerton (10.0).

Mr. S. G. Clift.

Mr. P. E. Kent.

Discussion on The red rocks (11.15).

Dr. R. L. Sherlock.—The origin of the red rocks of the North Midlands.

Late in Carboniferous time Britain was greatly elevated, but the mountainous country suffered rapid erosion of the soft coal-measures strata. Grey detritus was oxidised in an increasingly drier climate into red beds. The red colour has been thought to be caused by chalybeate waters percolating through green beds, but the geological evidence favours both colours being primary, although red may be altered to green superficially. Green strata probably indicate wetter climates breaking the more arid periods, the most notable being the Tea-green Marls closing the Keuper. Cheshire was probably a sinking land area throughout the period and
several thousands of feet of red beds accumulated there. In Nottinghamshire the sea extended from Germany up to the Pennines which were rising, at intervals, during the period. On the coast, breccias, dolomite, and red marl formed according to the varying depth of the sea, and on the shore dunes were spread. Gypsum-beds were evidently deposited from the sea, which twice dried up, but the mass of the mineral offers a problem. The Midlands rocksalt is of lacustrine origin.

The dolomitic sandstone of Mansfield represents a sandbank formed opposite the mouth of a river.

Mr. F. W. SHOTTON.—The Aeolian deposition of the Lower Bunter of Worcestershire and East Shropshire.

The areas of Lower Bunter outcrop examined, over a number of years by the Lapworth Club of Birmingham University, comprise three north-south strips separated from each other by strike faulting, and lying approximately in the triangle with Oakengates, Bewdley and Stourbridge at its corners. Every exposure accessible in the area was examined, and dip readings were taken, and sketches made of each unit of false-bedding. These readings, over a thousand in all, were examined statistically. A considerable number of rock specimens, including a regularly spaced series over 500 feet of a core, were examined for grain-size variation. The main conclusions reached were:

1. Every portion of the Lower Bunter is false-bedded.
2. Wind deposition is responsible for all the deposit.
3. The false-bedding is consistent with a constant wind direction combined with an increasing bulk of sand.
4. The wind blew consistently from the east, from the direction of the Mercian Highlands.
5. The sand is 'millet seed' down to a diameter of about 0.18 mm.
6. The sand is amazingly well graded, not only in individual samples, but in the deposit as a whole. Apart from pebbles which may occur in the bottom few inches of the deposit, no particles exceeded 1.1 mm., and there are no clay or silt bands. The median diameter of particle for the whole deposit is 0.20 mm., and 90 per cent. lies between the ranges of 0.50 and 0.10 mm.

Mr. A. N. THOMAS.—The Triassic rocks of north-west Somerset.

The area in which the Triassic rocks are to be described lies between Porlock and Williton. The lowest deposits of the New Red Sandstone in the corridor between the Quantocks and the Brendons are usually classed as Permian. West of Williton, they are overlapped by Bunter Pebble Beds and finally by Keuper Sandstone and Keuper Marl, which in Dunster Park rests directly on Devonian. The sub-Triassic surface is highly irregular and the earliest deposits fill in isolated valleys and depressions, their outcrops subsequently connected by the more widespread later deposits. In Bunter times the area between Williton and Minehead formed part of the main south-west basin in which were deposited conglomerates formed of pebbles of Carboniferous limestone and Devonian Grit.

The Vale of Porlock formed a separate basin, which was filled in by Bajada breccias of very local derivation. The pebble composition of the breccias shows a striking correlation with the Devonian rocks of the immediate hinterland. These breccias were deposited in fans that, originally isolated, finally coalesced and were covered by the waters of the Keuper Lake.
This lake, which united the Porlock cuvette with the main area, was highly calcareous, and the earliest deposits were cornstones succeeded by Red Marls passing up into Red and Grey Marls.

The change in conditions of deposition and lithology is accompanied by a change in the character and persistence of heavy mineral suites.

Dr. S. E. Hollingworth.—*The gypsum deposits of the Vale of Eden* (12.45).

Recent borings north-west of Appleby have added considerably to our knowledge of the Permo-Trias there, especially in the poorly exposed beds between the Penrith and St. Bees Sandstones. Three distinct horizons at which thick beds of gypsum or anhydrite occur can be recognised in the 'Permian' Hilton Plant Beds.

Dr. R. L. Sherlock has successfully used such chemical precipitates as a basis for correlation in the Keuper, and in the Permo-Trias of North-East England. They represent periods of desiccation of considerable magnitude and so are probably due to regional climatic changes. Consequently it is reasonable to suppose that where sequences of such deposits are found in adjacent areas they are correlatable. This reasoning would appear to apply whether the areas concerned represent separate basins of deposition or detached portions of a once continuous region of deposition.

A comparison of the Vale of Eden sequence with that in the Durham Salt-field, and with that proved in boring to the concealed coalfield of South Yorkshire indicates the following as a probable correlation.

The lowest horizon (base of Hilton Plant Beds) corresponds with the lower salt (and anhydrite) horizon at the base of the Permian 'Middle Marl.' The two higher horizons lying about 200 ft. higher up, and separated by 10–14 ft. of marl west of the Pennines, are equivalent to the upper salt (and anhydrite) horizon and the upper anhydrite respectively which are usually separated by 20–30 ft. of marl.

Correlations with the Gypsum-anhydrite horizons of the Carlisle Basin, West Cumberland and Furness, indicate the probability of a lateral passage from 'Permian' Hilton Plant Beds to 'Triassic' St. Bees Shales.

Other facts of significance in correlations on climatic basis were indicated.

**Afternoon.**

Excursion to Ashover Inlier: quarries of the Clay Cross Iron Co., Ltd. Leader, Mr. W. H. Wilcockson.

**Friday, September 3.**

**Presidential Address** by Prof. L. J. Wills on *The Pleistocene history of the West Midlands* (10.0).

Mr. A. L. Armstrong.—*Evidence for climatic variations in the Pleistocene revealed by excavations at Creswell Crags, Derbyshire* (11.15).

The stratified deposits in the Pin Hole Cave, totalling 20 ft. in thickness, reveal evidence of three cold periods, separated by three periods of warm climatic, or inter-glacial, conditions. All the inter-glacial phases are associated with human occupation of the cave, the first and second deposits containing artifacts of Mousterian culture only. In the third inter-glacial phase the Mousterian culture is confined to the base of the deposit and
succeeded by cultures of Upper Palaeolithic age; Proto-Solutrian and Upper Aurignacian in character.

Mother Grundy’s Parlour and a rock shelter recently excavated at Whalley, confirm the evidence of the Pin Hole and indicate that man continued to occupy the area throughout the final cold period and to do so until early Mesolithic times.

**Dr. C. Fenner.**—*Australites: a unique shower of glass meteorites (11.45).*

The small glass objects, known as tektites, which have been found profusely scattered over small localised areas of the earth’s surface, are not generally agreed upon as being glass meteorites. On the Continent, such objects are displayed in museums as glass meteorites. In North America they are not represented at all. And in Britain the tektites are displayed alongside the meteorites, but not finally accepted as being of cosmic origin. The purpose of the present paper is to support the theory that tektites are glass meteorites, and more particularly to describe the characters and distribution of the great shower of glassy blebs, called Australites, that was strewn across the southern half of Australia at some time geologically recent but historically remote, most of the objects being to-day found upon the surface.

There are several series of tektites known: Moldavites, Billitonites, Indo-chinites, Rizalites, Australites, Darwin Glss, Ivory Coast Tektites, ? Libyan Glass, ? Columban Tektites, ?? Texan Tektites. Each series has well-marked characters of form, composition, and distribution. It is suggested that the only theory consonant with all the known facts is that which accepts tektites as glassy meteorites.

**Dr. J. E. Richey.**—*The tuffs in the volcanic vents of Ben Hiant, Ardnamurchan (12.15).*

The present investigation extends an observation of H. H. Thomas that a tuff from Ben Hiant contained much quartz and white mica. In addition, garnet is now recorded. The source of these minerals is concluded to be the Moine Schists, which underlie the Tertiary Plateau Basalt Lavas. The latter rocks form the walls of the great craters at the level of the tuffs. A tiny fragment of garnetiferous quartzose-schist in a tuff strengthens the conclusion. The tuffs also contain much finely divided basalt and trachytic and glassy materials. The last-mentioned belong to the explosive magma.

The tuffs alternate with agglomerates in flat layers, filling two craters, and in the later crater andesitic pitchstone lavas occur at intervals. The layers show no bedding internally. An agglomerate layer mainly with trachytic rock-fragments grades upwards into tuff, at the top of which, at the base of the overlying agglomerate, a dividing-plane is usually apparent. Each pair of layers of agglomerate and tuff is regarded as the product of a single eruption. Their thickness averages 20 to 30 ft.

The exceedingly fine grain of the tuffs indicates that the later phase of each eruption was highly explosive. This, coupled with the composition of the tuffs, suggests gaseous erosion of the volcanic pipe such as F. A. Perret observed in the 1906 eruption of Vesuvius.

**Prof. S. H. Reynolds.**—*A collection of reptilian bones from the Oölite near Stow-in-the-Wold, Glos. (12.45).*

The remarkable series of bones described below was obtained by Mr. C. I. Gardiner, the Curator of the Museum at Stroud, where they are now
preserved. Four groups of reptiles are represented, viz.: Crocodiles, Theropod, Sauropod and Armoured dinosaurs.

The Crocodilian remains, all attributable to Steneosaurus, are the most plentiful. Next in point of numbers are those of the Theropod dinosaur Megalosaurus, which is represented by vertebrae, part of a mandible, a sacrum, two coracoids, an ilium, an ischium, a femur and parts of the scapula and humerus. The Sauropod remains, no doubt to be attributed to Cetiosaurus, are less plentiful but include a caudal vertebra, two ribs, a coracoid and two ischia.

In some respects the most interesting find was two dermal plates of Stegosaurus.

Prof. S. H. Reynolds.—A section of Rhaetic and associated strata at Chipping Sodbury, Glos.

The section is seen in the big Carboniferous Limestone quarry north of the village.

The interest of the section lies in:

1. The fine development of the Rhaetic, particularly of the bone bed, which is in part of a coarsely conglomeratic character and resembles that of dust.

2. The nature of the Palaeozoic surface, which in the western part of the quarry shows the uneven character due to sub-aerial erosion, while in the eastern part it is planed down to a level platform, the later stages at any rate of the levelling being doubtless the work of the Rhaetic sea.

3. The fact that parts of the Carboniferous Limestone platform stand at different levels, this being clearly the result of thrust faulting of post-Rhaetic date which followed the bedding planes.

Afternoon.

Excursion to Harworth Colliery. Leader, Mr. J. M. R. Watson.
Excursion to Kimberley and Bulwell. Leader, Prof. H. H. Swinnerton.

Saturday, September 4.

Excursion to Lincoln district. Leaders, Prof. A. E. Trueman and Mr. P. E. Kent.

Sunday, September 5.

Excursion to Derbyshire (Matlock and Dovedale). Leaders, Prof. W. G. Fearnsides, F.R.S., and Dr. R. G. S. Hudson.

Monday, September 6.

Joint Discussion with Section E (Geography) on The potential mineral resources of Nottinghamshire and Lincolnshire, and their geographical significance (10.0).

Prof. H. H. Swinnerton.

The accessory resources essential to the development of this region relate to the need for water supply and for material for use in constructional
works. Since the region is one of low relief, storage of water in reservoirs 
plays an insignificant part. The River Trent supplies some of the needs 
of neighbouring industrial concerns and is a waterway of much value. 
A huge reserve of water for human consumption is preserved in the Bunter 
Sandstone and is the chief source of supply for Nottingham and many other 
towns and a much larger number of villages. The Lincolnshire Limestone 
holds a large volume of water which unfortunately fluctuates greatly with 
the seasons. The Spilsby Sandstone is proving a valuable reservoir for 
East Lincolnshire. The chief building stones of the area are provided by 
the Magnesian Limestone north of Mansfield and the Lincolnshire Lime-
stone at Lincoln and near Ancaster. The latter is also extensively used in 
making foundations for roads. The Keuper Marl near Nottingham and 
the Liás clays at Lincoln and Grantham supply material for brick making. 
The floor of the Trent valley and the terraces on either side provide vast 
stores of gravel for concrete and for road surfaces. A narrow belt of 
country running north and south through the area provides hydraulic 
limestones for making cement and gypsum for making plasters. The 
Lincolnshire wolds also contain extensive beds of cretaceous iron ore.

Mr. S. G. Clift.

The exploitation of the Nottinghamshire Concealed Coalfield only dates 
back to 1859 when the Shireoaks Colliery struck the Top Hard seam at 
a depth of 1,500 ft. beneath the Permian limestone. The progressive 
easterly movement of collieries has made two facts clear, the one that the 
cover of newer rocks increases eastwards at a rate of 100 ft. to the mile, the 
other that the folds and faults of the visible field continue undiminished 
under that cover.

The normal easterly dip of the seams soon gives place to a pronounced 
rise and what was thought to mark the eastern rim of the field has proved 
to be but one of those concealed folds. A borehole to the east of the River 
Trent has proved the existence of valuable reserves of coal beneath Lincoln-
shire. Though the eastern limit is conjectural, the limit of exploitation 
under modern conditions cannot extend much beyond Lincoln where the 
overburden of newer rocks reaches 3,000 ft.

The coals of Nottinghamshire are primarily house and industrial fuels 
of low-ash content and free burning qualities. The lower seams of the 
Middle Measures maintain their thickness eastwards and must form a vast 
potential reserve. The thinning of the Coal Measures in a S.E. direction 
does not affect the coal seams to the same extent.

The field is an original basin of sedimentation with the basin-like character 
accentuated by pre-Permian movements.

Advances in the technique of sinking have made possible the exploitation 
of Coal Measures lying beneath heavily watered strata, but the effects of 
colliery subsidence on water undertakings situated on the Bunter Sandstone 
are being watched with anxiety.

Dr. D. A. Wray.

Recent investigations made on the cores obtained from deep borings 
on the borders of Lincolnshire appear to have an important bearing on 
the probable easterly extension of the East Pennine coalfield. Two borings 
carried out not far from the Trent and ten miles to the north of Gains-
borough revealed some 1,700 ft. of Coal Measures underlying 1,500 ft. of 
Permian and newer rocks. From the evidence of the non-marine lamell-
branch found, all the productive Coal Measures were represented, but in
this region they are less than half the total thickness of the corresponding measures in South Yorkshire. In addition, all the seams of coal show a marked deterioration in an easterly direction, and if these conditions persist to the east of the Trent there would appear little hope of workable coal being encountered in North Lincolnshire.

A re-examination of the materials of the Doddington or Harly boring (six miles due west of Lincoln) revealed the presence of the Tenuis Zone of Trueman, and the highest Coal Measures here are undoubtedly to be correlated with the Upper Coal Measures of North Staffordshire and other British coalfields. This is probably true of most, if not all, of the Red Coal Measures recorded in numerous adjacent borings and sinkings. The Upper Coal Measures thicken in an easterly direction, and at their base has been discovered a pronounced unconformity or discordance. Thus while there are only 230 ft. between the Top Hard Coal and the base of the Upper Coal Measures at Harly or Doddington, the corresponding measures are no less than 2,250 ft. thick at Maltby, 24 miles to the north-west. If this overstep continues at a uniform rate to the east, there is little likelihood of workable coal being found to the east of the city of Lincoln.

The writer concludes from the foregoing observations that the eastern limit of the concealed coalfield can now be fairly precisely defined.

Prof. W. G. Fearnsides, F.R.S., Mr. O. D. Kendall, Mr. S. H. Beaver, Mr. K. C. Edwards, and Prof. C. B. Fawcett.

Afternoon.

Excursion to Bunny and Normanton Hills. Leader, Mr. S. G. Clift.

Tuesday, September 7.

Dr. Rudolf Richter.—Problems of sedimentation and the advantages of a Marine Geological Laboratory (10.0).

The author describes the scientific researches carried on in a marine station for geologists, which has been established by the Senckenberg Natural History Society of Frankurt-am-Main on the German coast at Wilhelmshaven. The deposition and reconstruction of sediments under various circumstances are studied. The life of the shore is also observed from the point of view of a geologist. Among other discoveries, it has been found that mussels facilitate and hasten the deposition of fine mud by swallowing it and converting it into hard pellets of excrement.

Prof. W. G. Fearnsides, F.R.S.—Report on work of the Critical Sections Committee (10.50).

Joint Discussion with Section L on The teaching of geology in schools. (11.15.)

Chairman: Mr. H. G. Wells.

Prof. A. E. Trueman.

In recent years there has been a steady decrease in the attention paid to geology in most schools, notwithstanding the great extensions in science teaching during the same period. In view of the crowded school curriculum,
geologists have been reluctant to press the claims of their subject, but recently attention has been drawn to the desirability of including it, at least as an optional subject, in the courses of senior and secondary schools.

The teaching of geology may be justified alike on cultural and on utilitarian grounds. It is claimed that some knowledge of the outlines of geology is an essential part of a liberal education, for some of the most profound changes in thought have resulted from the growth of the science; on the other hand, most of the raw materials of industry are obtained from the earth's crust and it is urged that applications of geology are not fewer than those of other sciences.

There are many reasons why geology is particularly suitable for introduction into schools. It is typically an observational science in which equipment is less expensive than in almost any other science, although much simple experimental work can be introduced. It affords opportunities to develop a scientific outlook even in those who do not carry their study of science to a higher stage; once an interest has been aroused it often lasts beyond school days, and adds to the enjoyment of holidays and travel. A pupil knowing nothing of other sciences may make a beginning with geology, yet this subject has so many contacts with every science that it forms a natural part of any scheme of general science.

Geology has particular claims for introduction into schools situated in areas which may be called 'natural geological laboratories' as well as into schools from which many pupils proceed to posts concerned with mining, agriculture, building and engineering. Suggestions for school syllabuses are embodied in the Report just prepared by a Committee of Section C; it is urged that these should allow great elasticity and that the character of the school area should determine the arrangement and bias of the course.

Prof. H. G. A. Hickling, F.R.S.

Geology and geography differ in their ultimate aims, but a very large proportion of their factual basis is common. Both are concerned with the form and distribution of the materials of the earth's surface, and equally with the nature, action and results of all the forces which are in daily operation upon and beneath it. The map gives a false impression of a static world. The movements of water and ice; the effects of rain, wind, and frost on the soil; the results of the growth of vegetation on the surface and of its removal; the changing coastline and its causes; the effect of earthquakes and of volcanic activity; climatic changes and their effects—these and countless other natural operations are fundamental data for the geologist and geographer alike. Human activity and development is conditioned by the present operation of these geological forces and by the results of their former actions. There can be no delimitation of the spheres of geology and geography in a proper presentation of the earth in its relation to man. The further civilisation progresses the more intimately are human relations involved with the results of geological processes.

For the reasons just indicated the demand for geologists is increasing. Minerals formerly unknown or regarded as mere objects for museums become vital raw materials. An ever-increasing range of metallic ores, rare earths and other mineral substances is brought into industrial use. The search for oil alone must occupy the attention of a very large body of geologists for a long period. There must be an unceasing demand for new sources, while the exploitation of each known field requires constant geological supervision. Prospecting for copper, tin, gold and other resources is now conducted on a scale not formerly contemplated. Methods
of geophysical prospecting, though often open to criticism, will become of wider application and make further demands on the geologist. Every country becomes increasingly concerned to discover and exploit the natural resources upon which its existence may ultimately depend and it is increasingly realised that the search for these must be based upon a complete geological study of the countries concerned. In this country the supply of geologists necessary for the development of the resources of the Empire is not being maintained. Steps must be taken to deal with the position, of which the first must be to make known that the need exists and that there are good careers in this field for men of real ability and good physique.

Mr. V. C. Spary.

It is a great advantage if a teacher of geography has had some geological training. A well-balanced course in school geography must include many lessons of a geological nature, and many lessons allied to history, economics, etc. How much geology is taken depends on the ability of the teacher (of geography), on the requirements of the geography syllabus, and on the locality in which the school is situated.

On the other hand, there does not seem to be room in the curriculum for geology and geography and general science. It is better for the pupil to learn his geology incidentally in the geography and science lessons.

Mr. J. Davies.

As a school subject geology has received but scant attention and few public examining bodies make any provision for it. Some educationists consider that it should not normally be included in the School Certificate scheme. It should, however, find a place among the advanced subjects for the Higher Certificate, while much of the subject matter might be taught to junior pupils in the general science and geography lessons.

Education, regarded as a preparation for life, would be incomplete without some study of geological principles, which are essential for an intelligent understanding of environment. A proper interpretation of natural development is based on the Theory of Evolution, which was formulated by investigators conversant with geological history. The earth's crust, with its vast economic resources, has ever commanded attention.

Afternoon.

Excursion to Old Dalby, Holwell and Barnstone. Leader, Mr. H. H. Gregory.

Evening.

Joint Discussion with Sections D, E, F, K, M, on Planning the land of Britain. See page 486.

Wednesday, September 8.

Dr. V. J. Novak.—The correlation of topographical features and sedimentary deposits (10.0).

A great part of the continents is drained by rivers which carry the material of rocks loosened by weathering to their lower courses, to lakes,
dry basins or the oceans. Marine, lacustrine, and desert deposits as far as they can be considered to be derived from the neighbouring land can be said, according to the late W. Penck, to stand in a correlation with processes which loosened their particles from the maternal rocks and transported them to their present place of occurrence. Penck even tried to make out correlation between deposits and land forms. This can, however, rarely be done reliably. Firstly, the preserved land forms are comparatively very young; the oldest of them are hardly younger than upper Tertiary. So the correlated sediments are, in a great part, still covered by the sea. Then, the large series of little changed deposits of terrestrial origin are correlated with times when erosion was rapidly going on in the land which supplied the material. So the features of the landscape there were changing rapidly and few of them could be preserved for any long time. On the contrary, little inclined forms of an advanced planation can be preserved much longer, or, at least, forms that succeed them on water divides do not differ from the original ones so much. But these persistent forms were modelled in a time when comparatively little material was exported from the region and accumulated outside of it. Besides, the sediments simultaneously laid down in the seas or lakes were exposed much longer to marine and lacustrine influences and more changed by them.

Sometimes valleys and other land forms filled with marine or lacustrine deposits are shown by them to be not much older than these sediments; but rarely can a whole system of topographic features formed at the same time be followed. In recent arid basins the chances to establish a correlation of topographical features and deposits seems to be better than elsewhere.

Some examples of correlated sediments and processes, in some cases of land forms also, form the Bohemian Massif, and the Alps are shortly described.

SECTION D.—ZOOLOGY.

Thursday, September 2.

Presidential Address by Prof. F. A. E. Crew on The sex ratio.

Discussion on the Presidential Address (11.15).

Mr. A. J. Marshall and Dr. J. R. Baker.—The sex ratio in the wild animal populations of the New Hebrides.

The sex ratio of most of the resident birds of the New Hebrides (Pacific Ocean) is high. If all the species collected by the Oxford University Expedition are lumped together, the percentage of males is \(57 \div 1.0\). More than fifty specimens were taken of each of twenty species, and among these males predominated in seventeen. The highest percentage of males was in the cuckoo, *Cacomantis pyrrhophanus* (82 \(\div 5.1\)) and in the honey-eater, *Myzomela cardinalis* (80 \(\div 3.6\)). The sex ratio of nestlings approximates to equality. In the fruit-bat, *Pteropus geddiei*, the males are 69 \(\div 3.3\) per cent. of the population. In the insectivorous bat, *Miniopterus australis*, however, the sex ratio is almost equality \(51 \div 1.9\) per cent. males). It is suggested that sex ratio is generally a non-adaptive character,
for the species could usually survive and multiply at the same rate with far fewer males. Except where the male protects territory or incubates or guards or feeds the female or young, its significance for the species is simply to act as a dice-box for the production of new combinations of genes.

Dr. W. O. Kermack.—*Secular trends in the sex ratio and some related topics* (11.35).

Dr. A. Walton.—*The experimental control of the sex ratio* (11.55).

Three possible methods by which the sex of animals may be controlled or the numerical proportion of the sexes altered by wilful manipulation are discussed. The first method is the induction of parthenogenesis of the egg. This occurs normally in many invertebrates and is a common mode of reproduction in some insects. In the vertebrates parthenogenesis has been induced in amphibia and to some extent in mammalia. The second method is the induction of sex reversal during development or in adult life. This also occurs normally in some invertebrates and abnormally or by experimental treatment in vertebrates. The third method is the separation of the male and female determining sperms and is applicable to animals including mammalia, in which the male is heterogametic. There is evidence that such separation does occur normally to some extent. The results obtained by experiment are as yet inconclusive, nevertheless the comparative ease with which the sperms can be subjected to experimental manipulation opens up a promising line of future investigation and the prospect of practical sex control.

Dr. P. C. Koller.—*The differentiation of the sex-determining mechanism* (12.15).

The diploid generation in higher animals and plants is sexually differentiated: one sex is heterozygous with an XY pair of chromosomes, while the other is homozygous having a pair of similar chromosomes, XX. There are various types of differences between the X and Y chromosomes which may be considered as evolutionary stages in the differentiation of the sex-determining mechanism. In higher organisms the sex chromosomes are structurally differentiated into a pairing and non-pairing or differential segment. The heterozygous condition of one sex is maintained by the suppression of crossing-over between those regions of the sex chromosomes which represent the genotypic differences in the sex-determining mechanism, the differential segments. The obligatory segregation of these segments is ensured by the homologous region in the X and Y chromosome.

Dr. E. B. Ford, Dr. C. Gordon, Mr. and Mrs. Culwick.

Afternoon.

Mr. C. H. Roberts.—*The effect upon fish of rain washings from tarred roads* (2.15).

The deleterious effects of rain washings from roads are due to both physical and chemical factors. There is an element of risk with any waterproof road surface whether this be of tar, bitumen or cement. When rain falls upon a waterproof road it is shed directly into the nearest stream, carrying with it dust, dung, fallen leaves and lubricating oil. The organic matter decomposes and acts in
much the same manner as untreated sewage. The lubricating oil has a bad effect upon smaller stream organisms such as insects. The dust tends to smother the water-weeds.

There is no doubt that washings from roads surfaced with ordinary tar contain such definitely poisonous substances as phenol, cresols, naphthalene and quinoline.

As England is a great producer of tar, this toxicity is unfortunate because road-engineers, to save themselves from the excreations of anglers, have used large quantities of non-toxic bitumen which is imported from abroad.

The tar industry, however, faced with this heavy loss, have not been idle, and have carried out much intensive research. Tars which are virtually non-toxic are now commercially available. Apart from their low toxicity, these tars have valuable physical properties which make them a formidable rival of bitumen.

Cement, when first laid, is dangerous because of its content of free lime but, when matured, it contains no substances which are poisonous to stream life.

Mr. F. T. K. Pentelow.—The growth of trout in acid waters (2.45).

Brown trout (Salmo trutta) vary greatly in their adult size. In general, in this country, fish living in alkaline, calcareous waters grow big (2 to 5 lb.) whilst those in neutral or acid waters never exceed a few inches in length or a few ounces in weight. In Sutherland there are certain lochs containing very soft, acid waters (pH 4.5) in which trout grow to 4 or 5 lb., whilst there are other neutral lochs (pH 6.5) in which the fish are small.

The geology, chemistry, flora and bottom fauna of these two types are briefly described and various theories of trout growth re-examined in the light of these data.

Mr. K. A. Pyefinch.—Wollaton Park Lake, Nottingham: a physico-chemical survey (3.0).

This is a brief account of the more important physico-chemical changes taking place in a small, shallow lake, based on a two years' survey.

Such temperature gradients as occur are purely transient, as they are abolished during the night or by a short period of unfavourable weather during the day. The annual changes of pH and oxygen are conditioned by the extent and by the type of flora; there is no midsummer stagnation period. Diurnal changes in oxygen content are often well marked.

The annual changes in phosphate, silicate and nitrate are generally normal, though there are anomalies in the phosphate readings. The abnormal summer rainfall of 1936 led to the inflow of water rich in phosphate and silicate, though the nitrate values were not much affected.

It is not possible to draw any definite conclusions as to the factors which may limit the development of the flora. Lack of phosphate has been generally quoted, but these investigations show that the limiting factor may vary from year to year and that observations made in the lake alone may be deceptive, as an inflow of water comparatively rich in the essential solutes may be going on all through the summer.

Mr. C. R. Stonor.—Some features of the courtship display of the Birds of Paradise (3.30).

Field observations and study of the birds in captivity shows that the remarkable displays of the Birds of Paradise are sexual in nature and are
not 'warning' displays. In some cases, the males gather together and go through the courtship dances in bands, while in others the display is performed alone, and often on a specialised dancing ground. A detailed study of the plumes of the different genera brings out the remarkably close relationship that exists between these structures and the mode of display; in the genus Paradisaea, several quite distinct types of display are found and correspond very closely with the slight inter-specific differences in the plumes, providing an interesting basis for the determination of the inter-relationships of the species.

Examination of the plumes, the pterylosis, the musculature, and the osteology of one of the more highly specialised types indicates a striking correlation of structure, apparently subservient to the display; and the whole consideration of the sexual adornments and the manner in which they are shown off opens up interesting lines of thought on the problem of relationship of habit to structure.

Friday, September 3.

J O I N T S Y M P O S I U M with Section K (q.v.) on Recent work in genetics and cytology (10.0).

A F T E R N O O N.

Semi-popular lecture by Mr. L. Koch on ' How I collected bird songs' ; illustrated by gramophone records. (2.15.)

We know that the knowledge of birds especially that of their song is not very widespread.

Some of the most beautiful lyric descriptions in our poetry and prose are of the glory of bird songs. How familiar in words are the sweet flute-like notes of the nightingale or the lulling and stirring songs of the woodlark. Yet could anyone hope to recognise the sounds in nature merely from having read these descriptions? Curves and music notes imply just as little.

It is only after half a century of development of that invention of Edison's primitive but epoch-making phonograph that one could venture to collect bird songs in the open by means of the microphone and the modern moving recording studio.

Further developments of the idea of a sound book that will add sound by means of gramophone records to text and picture, is shown with British bird songs. Here we have a description of the extraordinary difficulties that are encountered and the endless patience required by all who are concerned in watching and collecting bird songs during the night and early dawn.

A number of interesting episodes of the 'expedition' illustrate the bird song hunting.

What bird song means and how it is uttered is mentioned and audibly rendered by natural clear examples of about twenty-five of our British wild bird songs. These records are not only a valuable asset to bird and nature lovers, but of great importance for education and science.

Exhibition of films of biological interest:

Behaviour and sense physiology in butterflies, by Dr. D. Ilse.

Courtship display of Birds of Paradise, illustrating Mr. C. R. Stonor's paper; shown by courtesy of Dr. J. S. Huxley.
A series of films prepared under the direction of Dr. J. S. Huxley and Mr. H. R. Hewer, shown by courtesy of the Gaumont-British Instructional Co., Ltd., including, among others:

Heredity.
Sea-urchin, Parts I and II.
Animals of the rocky shore.
Polyps and jellyfish.

Saturday, September 4.
Excursion to Dovedale and the Peak district.

Monday, September 6.

Prof. C. M. Yonge.—The biology of certain Prosobranch Gastropoda (Aporrhais and Pterocera) (10.0).

Unlike the Lamellibranchia, which are a homogeneous Class, the Gastropoda have become specialised for a wide variety of habitats. The most striking examples are the planktonic and parasitic groups. But specialisation amongst the bottom living Prosobranchs is equally important. The cases of Pterocera and of Aporrhais are here discussed.

The primitive Prosobranch may be regarded as an animal possessing a creeping sole, a radula used for scraping, and a digestive system capable of dealing with an omnivorous diet. Such an animal would creep over rocks and feed on the encrusting flora and fauna.

Pterocera is a genus of the Strombidae common in the Indo-Pacific. The animals live on the sandy areas on the surface of coral reefs. The elongated operculum is dug into the sand and the animal moves by a series of convulsive contractions of the pedal muscles. The radula is adapted for cropping delicate algae, and the digestive system possesses not only a crystalline style—indicating a herbivore feeding on finely divided food—but also a powerful cellulase for breaking down the cell walls of the algae.

Aporrhais, undoubtedly allied to the Strombidae, lives in northern latitudes and down to considerable depths on muddy bottoms. It is specialised for burrowing in mud. Movement over a hard surface is essentially the same as in Pterocera. Feeding is by means of an extensile proboscis armed with a radula adapted for seizing particles of organic debris. The gut possesses a style and there is a complicated sorting mechanism in the stomach but no cellulase.

Mr. J. Z. Young.—The structure and functioning of the higher nervous centres of Cephalopods (19.30).

The behaviour of Octopus, Squid and Cuttlefish is probably more complex than that of any other invertebrates, but no thorough study has yet been made either of their capacities or of the structure of their central nervous system. The present investigation of the morphology and connections within the nervous system has shown that besides possessing nerve fibres larger than those of any other animal, making possible the very quick darts of a Squid through the water, these animals also have very elaborate higher nervous centres, containing immense numbers of smaller neurons.
These centres are so arranged as to provide a system which is potentially capable of performing the most complex feats of sensory discrimination, learning and modifiable behaviour, fully justifying the impression of the superficial observer that these animals show a high degree of ‘intelligence.’

Although we know very little of the physiological basis for such phenomena yet we may say that they depend on the presence of (a) sensory centres in which nerve impulses from various parts of a sensory surface, say the eye, are able to interact, giving the possibility of the recognition of shape: the Cephalopods possess such an apparatus in their large optic lobes; (b) centres in which impulses from various sensory systems converge and are correlated to give an appropriate reaction; (c) centres in which constant nervous activity is maintained in definite patterns throughout the life of the animal by self-re-exciting chains of nerve cells. This constant activity may provide the basis for ‘spontaneous’ activity in complex patterns and for the modification of these patterns by learning and experience.

The supra-oesophageal ganglia of Cephalopods contain systems of both types (b) and (c), since fibres from various afferent sources converge and play upon common neurons which then activate the motor centres for the control of swimming, seizing, biting, etc. These highest centres are contained in the lobus verticalis, a structure which increases in relative size during the post-larval life of the animals.

The motor centres lie in the suboesophageal ganglia, which are best considered as derived from ganglionated cords of the type found in Amphineura and, already much shortened, in Nautilus. The three great groups of muscles by means of which overt behaviour is produced are those of the arms, for seizing, of the retractors and mantle for rapid movement by the ejection of water, and of the fin for slow movements. The first two are controlled by motor neurons of the pedal and brachial and the palliovisceral ganglia respectively. Dominating these lowest motor centres there is in Decapods a special higher motor centre, the lobus magnocellularis containing giant cells whose processes pass into the pedal and palliovisceral ganglia and produce the simultaneous contractions of the muscles of the tentacles, retractors and mantle which are involved in the quick darts after the prey.

The more gentle and subtle movements of the fins are produced by the cells of a special lobe of the palliovisceral ganglion which is controlled by a direct pathway from the cerebral centres.

Mr. E. J. W. Barrington.—*The structure and function of the digestive system of Amphiopus (ii.o).*

Several types of secretory and ciliated cells are distinguishable in the epithelium of the mid-gut diverticulum and hind-gut, and there is an elaborate system of ciliary mechanisms for manipulating the food and secretions. Digestive secretions are swept out of the diverticulum in a ventral ciliated tract, and wound into the food-cord which is set into rotation by the powerful ciliation of the ilio-colon ring; secretions from the mid-gut are also added to it. Particles of mixed food and secretion are broken off from the rotating mass and distributed over the epithelium for absorption, which takes place mainly in the hind-gut, the particles being driven along this partly by the oblique beat of the cilia in the ilio-colon ring and partly by a dorsal ciliated tract leading backward from the mid-gut. Some absorption probably occurs also in the diverticulum and mid-gut, but much of the scattered material in the latter region is returned to the main cord by a lateral ciliated tract on the left wall. There is good evidence that absorption is associated with the ingestion of solid material.
Mr. R. J. Whitney.—Research in experimental Zoology in progress at Birmingham University (11.30).

Professor H. Munro Fox has been responsible for the initiation at Birmingham of several lines of research concerned with the metabolism of aquatic animals. At present he is himself investigating the metabolic and developmental rates of animals from different latitudes.

Dr. Minnie L. Johnson is re-investigating the function of haemoglobin in the earthworm, employing modern experimental methods.

Miss Rosalie F. Griffith, continuing Professor Fox's earlier work on chlorocruorin, is studying its respiratory function in Sabella.

Mr. Cecil A. Wingfield, continuing earlier work initiated by Professor Fox and others, is examining the differences between pond and stream animals from the point of view of available oxygen. Mr. Reginald J. Whitney treats the same problem from the point of view of prevailing temperature.

Mr. H. G. Newth is determining the factors initiating the swarming of Vorticella which he and Professor Fox have observed.

Dr. D. L. Gunn, with others, is continuing his earlier work on the behaviour of terrestrial arthropods towards temperature and air humidity. He is also re-investigating the avoiding reaction of Paramecium.

Dr. Otto Löwenstein is investigating the functions of the semicircular canals in fishes, and is also taking up research on the tunicate nervous system.

Mr. L. C. Beadle.—Experiments on the growth and differentiation of hydroid tissues (12.0).

Experiments have been done mainly with the brackish water hydroid Cordylophora lacustris. Like some other hydroids and sponges the tissue (in this case the cystalloec) can be dissociated into minute fragments which will aggregate into masses and ultimately reconstitute new individuals. Contrary to the conclusions of previous workers on hydroids the experiments indicate that the cells do not dedifferentiate to an embryonic condition, but that those of each layer maintain their own individuality throughout dissociation and reconstitution. That the so-called 'interstitial' cells form a reserve of totipotent regenerative cells seems to be disproved. The position from which the new hydranth develops from a mass, normally unpredictable, can be determined by the engrafing of an oral cone. This therefore acts as an 'organiser.' Experiments done to throw some light upon the nature of this action show that it does not depend upon the orientation of the graft and that a variety of inhibiting agents have a more powerful action upon the self-organising capacity of the mass than upon the organising action of the engrafted cone.

Dr. F. D. Ommaney.—Seasonal movements of Copepoda in the Antarctic (12.30).

In the Antarctic zone the movements of the plankton are in general influenced by two water layers—'Antarctic Surface Water,' flowing northwards and eastwards above 250 m., and 'Warm Deep Water' flowing southwards below that depth. It has already been demonstrated that several species of macroplanktonic organisms inhabit the Antarctic surface water in summer and sink into the warm deep water in winter so that a circulation of the plankton is established. During the recent voyage of the R.R.S. 'Discovery II' this circulation was further studied in relation to certain Copepod
species. In the summer these species occupy the upper layers above 100 m., but after the summer spawning the new generation, as it approaches the older stages, sinks down into layers below 250 m. The gradual descent of the older individuals of the new generation is demonstrated. In colder Antarctic water the spawning is delayed and the growth of the summer generation is retarded so that at mid-winter a population may be found still consisting almost entirely of young stages and the descent from the surface may thus take place later in colder water near the ice edge than in warmer water farther north. Winter is a resting period when little growth occurs, but in the spring the ascent to the surface takes place by the upward migration of late juveniles and adults preparatory to the summer spawning.

**Afternoon.**

**Dr. H. W. Miles.—The fruit-infesting sawflies of Britain (2.15).**

There are eight or nine species of *Hoplocampa* in Britain and they appear to be associated almost exclusively with the order Rosaceæ and the genera *Pyrus* and *Prunus*. The biology of several of the British species has now been studied in some detail.

*Hoplocampa testudinea* Kl., infests the fruits of the apple *Pyrus malus*, and *H. flavia* Lin. infests the fruit of *Prunus spinosa* and *Prunus domestica* and its varieties. These two species of sawflies have the flight periods coinciding with the blossoming period of the host plants. They oviposit in the calices and the young larvae tunnel into the developing fruit, each larva often invading several fruits before it attains maturity. Both species are univoltine but there is some evidence that a proportion of the larvae have delayed development and spend almost two complete years in a resting condition in the soil. This phenomenon appears to be associated with the food specialisation of the species and Speyer in Germany has recorded a similar circumstance in *Anthonomus pomorum*, a fruit-blossom infesting weevil in which a certain proportion of the adults live for two years.

Certain varieties of apples and plums appear to be more susceptible to attack than others by the sawflies. Within the last two years *Hoplocampa brevis* Kl., which has been known for some time on the Continent, has been discovered infesting pear fruits in a garden in Cambridge but so far its distribution in Britain is not known. Of the remaining species, *H. crataegi* Kl. and *H. pectoralis* Th. are associated with hawthorn fruits, *H. ariæ* Benson with the fruits of Whitebeam, and *H. alpina* Zet. with the fruits of Mountain Ash.

Little is known of the biology of *H. chrysorrhæa* Kl. and *H. rutilicornis* Kl., but they appear to be associated with *Prunus* species.

The particular interest in the sawflies of the genus *Hoplocampa* occurring in this country is that they all exhibit the fruit-infesting habit in the larval stage and there is a co-ordination of the flight period of the adult insects with the blossoming period of the host plant.

**Mrs. K. Grant.—A historical study of migrations in certain hawkmoths (2.45).**

Outbreaks of the American and European sub-species of *Celerio lineata* were studied from journals and from records collected by the Insect Immigration Committee of the South-Eastern Union of Scientific Societies.

It is suggested that both sub-species originate in semi-desert areas, and this idea is supported in the case of the American sub-species by showing that a correlation exists between outbreaks of the moths and a certain
sequence of desert rainfall. No correlation is found between European outbreaks and the rainfall of those North African meteorological stations for which records are available, but this may be due to the paucity of suitable figures.

Records are available for Europe over a period of one hundred and thirteen years, and for America for sixty years. A tendency is found for both years of unusual abundance and years of scarcity to occur simultaneously in Europe and America, showing that the cause of the outbreaks must be sought in some factor common to the two continents. There seems to be some correlation between outbreaks and the sunspot cycle, but the figures are barely significant. The outbreaks tend to occur away from the sunspot minima.

Mr. A. Roebuck.—The chafers of Nottingham and Lincolnshire (3.15).

Tuesday, September 7.

Dr. Flora E. Cochrane.—The activity of genes in development (10.0).

Work on the development of eye pigment in Drosophila has shown that pigment normally appears in the eyes at two distinct though consecutive times during pupal life. Eye-colour mutant genes affect either or both of these phases of development but allow the remainder of the development to proceed as in wild type. Histological studies have shown that eye-colour is due to the presence of pigment granules in definite pigment cells of which there are two kinds. Genes which affect eye-colour do so by altering the distribution of these granules, usually by suppressing their formation or by retarding their development; no gene acts to increase the number of granules beyond the number present in wild type. All genes so far recorded, with one exception, have a quantitative effect, the effect in the exceptional case being qualitative.

Studies of the testes of wild type and various mutants of Drosophila pseudo-obscura have shown that their colour appears and develops at the same time as the late phase eye pigment appears. It has also been shown that the genes which affect the eye pigment laid down during the late phase of development affect the testis colour in the same way and to the same extent while genes which affect the early phase of eye pigment development only, have no effect upon testis colour.

Mr. H. D. Slack.—Chromosome behaviour and taxonomic groups (10.30).

The value of chromosome behaviour as a means of providing further data for the demonstration of taxonomic relationships in animal groups has been recognised by many investigators. This comparative study deals principally with a single sub-order of insects, the Hemiptera-Heteroptera. About forty species were collected from one district, the country surrounding the city of Edinburgh. These are distributed among five families representing the two primary divisions, Gymnocerata and Cryptocerata. Studies of equivalent stages of chromosome behaviour in the development of the male germ cells are used to compare cytological grouping with phenotypic characters on which the taxonomic relationships are based. The systematic positions of the species represented are such as to allow comparison between the two primary groups, between families within these groups, and between smaller units within the families. By this treatment substantiation or insubstantiation of relationships implied by structural similarities is demonstrated and
a certain evaluation obtained of the rôle of cytology in the sphere of systematic classification.

Prof. E. A. Spaul.—*The anterior pituitary and secondary sexual characters (II.0).*

Dr. V. B. Wigglesworth.—*The rôle of hormones in the growth and reproduction of insects (II.30).*

Experiments on the blood-sucking bug *Rhodnius* show that moulting is brought about by a hormone secreted into the blood. A hormone is also responsible for preventing metamorphosis in the young stages of this insect; so that by suitable experiments it is possible to produce diminutive adults from first-stage nymphs newly hatched from the egg, or giant nymphs instead of adults from fifth-stage nymphs. The hormone which prevents metamorphosis throughout nymphal life is secreted by the corpus allatum. In the adult another hormone from the corpus allatum is necessary for egg-development in the female and the proper activity of the accessory glands in the male.

Mr. H. Waring.—*Colour change in elasmobranchs (12.0).*

With few exceptions, all Elasmobranchs so far investigated pale (contracted melanophores) on an illuminated white background and darken (expanded melanophores) on an illuminated black background.

It is established that in all these fish, the dark phase results from the secretion of a blood soluble hormone by the neuro-intermediate lobe of the pituitary. In regard to the mechanism underlying the pale phase, however, work on different species has led to divergent opinions. Thus, it has been shown that in certain English species of *Raja* and *Scyllium* the pale phase is dependent on the anterior lobe of the pituitary and not on direct nervous control of the melanophores. On the other hand, American workers have concluded that in *Mustelus canis* paling is brought about by direct nervous control of the melanophores; but the rôle (if any) of the anterior lobe of the pituitary has not been investigated.

The present paper analyses the possibility of different paling mechanisms within the group Elasmobranchii, particularly in the light of some new observations on the dogfish *Acanthias*.

Prof. E. Raymond Hall.—*Variations in American stoats (12.30).*

**Afternoon.**

Dr. R. J. Pumphrey.—*The evolution of hearing (2.15).*

It is customary to make an arbitrary distinction between the senses of 'hearing' and 'feeling.' This distinction is based on introspection and is due to the peculiar nature of the mammalian ear. In more primitive animals it vanishes and we can distinguish only more and less sensitive receptors for mechanical stimuli.

The passage of a train of sound waves through a medium is accompanied by two dependent processes, an oscillation of the molecules of the medium about a mean position, the *displacement* and a rise and fall of *pressure* about a mean value. Either of these properties may be used to estimate the intensity of the sound, and sense-organs sensitive to sound can be divided
into displacement receptors and pressure receptors. The former are the more primitive. In vertebrates the transition from the former to the latter type can be shown to be a necessary consequence of the transition from a life in water to a life in air. In insects the pressure-receptor type has arisen independently and both types may co-exist in the same insect.

Much less is known about the secondary properties of the auditory system on which frequency discrimination and localisation depend. Frequency discrimination is highly developed probably only in birds and mammals, though it exists feebly in fish and probably in some insects. Localisation is poor in man but good in mammals with a moveable pinna, and very good in some insects.

Mr. J. W. S. Pringle.—Senses of movement and position in the insect (2.45).

It is well known that man and the higher vertebrates possess a highly developed sense of limb position and muscular tone, which enables them to perform co-ordinated movements. Insects, also the highest members of their branch of the animal kingdom, have senses with a similar function, though their very different general morphology makes for differences in the mechanisms.

The position sense in man is served to some extent by endings in the joint surfaces. In insects groups of hairs are present in the joints, and the excitation of these varies with the degree of flexion. The force of movements is measured in man by the tension set up in the contracting muscles. In insects, by contrast, the most important sense organs are embedded in the skeleton, and react to the resulting compressions.

By recording electrically the impulses in the nerves it is possible to study in detail the working of these senses.

Dr. D. Ilse.—Studies on the sense physiology and habits of butterflies (3.15).

Evening.

Joint Discussion, with Sections C, E, F, K, M, on Planning the land of Britain (8.0). See page 486.

SECTION E.—GEOGRAPHY.

Thursday, September 2.

Prof. E. G. R. Taylor.—Robert Hooke and his services to cartography, 1666–1696 (10.0).

Hooke's scientific work was in direct response to contemporary needs. Merchant enterprise necessitated maps, maps necessitated survey, survey necessitated instruments of precision. Hence instrument making was Hooke's constant preoccupation. Meanwhile his services were at the disposal of such contemporary geographers and surveyors as Jonas Moore, John Ogilby, William Morgan, Moses Pitt and Robert Plot. He was adviser to John Adams, whose triangulation of England and Wales, begun in 1681, was to have established the map of England on firm foundations as Cassini had established the map of France. But the support of science
was left to private pockets and the enterprise failed: the period of the Revolution was barren until a beginning of mapping world distributions was made by Edmund Halley, upon whom Hooke had exercised a formative influence.

Mr. K. C. Edwards.—The geography of Nottingham (10.45).

The municipal boundary (1932) embraces a greater number of geological formations than that of any other city save possibly Bristol and these yield a rich diversity of natural resources. The Bunter Sandstone (Pebble Beds) provided the site of the earliest settlement at Nottingham, the lithological characters and surface topography of this deposit combining to give a marked individuality to the old town. Recent excavation of ancient caves may throw light upon the pre-medieval extent of the town.

Nottingham's commercial importance results largely from its position in the valley of the Trent, a situation deriving its advantages from (i) the crossing of the river, (ii) the convergence of routes and (iii) the virtual limit of navigation. The position is also marginal between north and south and between the Pennines and the eastern lowlands, affording a natural trading centre whose markets for both agricultural and manufactured goods preserve the tradition of Lenton Fair (circa 1164), and Goose Fair (ante 1284).

The presence of coal of a particular rank and quality, while not determining the precise nature of manufactures, was primarily responsible for Nottingham's industrial growth. To-day more than adequate supplies are available from farther north, and certain limitations mainly connected with the exploitation of the Top Hard Seam attach to future workings in the neighbourhood of the city which is, therefore, becoming relatively less important as a mining centre.

Dr. S. W. Wooldridge.—A comparative study of the morphology of the North Downs and the Chiltern Hills (11.15).

Few would deny that any attempt to explain the existing geographical features of south-east England must take account of two major geological episodes—the Mid-Tertiary folding and the deposition of the glacial drifts. Another episode of equally great importance has been tacitly ignored in most accounts of the area, viz. the trespass of a Pliocene sea, which apart altogether from its deposits, now reduced to the condition of a widely scattered group of ill-defined outliers, left an important legacy behind it in the form of a distinctive wave-cut bench backed locally by a degraded cliff feature. The bench can often be traced when the veneer of deposits has been completely removed and thus remains as a broad 'Pliocene facet' on the Chalk Downs. In this communication the Pliocene coastlines and off-shore platforms are traced, not only in the North Downs and Chiltern Hills, where their presence has been known for some years, but also in the region west of Reading. Over the area of the former Pliocene sea the drainage system has been superimposed from a sheet of pliocene sand and shingle, and notable contrasts in drainage pattern and general morphology are encountered on crossing the former coastline. Various anomalies in the present and former course of the Thames become explicable on a basis of the sequence of events deduced, and of even greater importance to geographers is the fact that the 'Pliocene facet' of the Downs presents characteristics of form and soil covering which differentiate it from other zones—e.g. the formerly sub-Eocene surface and the crest-regions. These differences have exerted a perceptible influence on human occupancy and
activity and thus afford a basis for a fundamental regional sub-division of the chalk tracts.

Mr. D. L. Linton.—The origin of the rivers of southern England (11.45).

It has been known for some twenty-five years that certain of the Hampshire rivers present anomalous and enigmatic relations to the structure of the country through which they flow. Such streams as the Itchen, Meon and Test flow directly across anticlinal ridges in a fashion which the workers of that day found very difficult of explanation. At first they naturally attempted to explain these puzzling features as modifications by capture of a drainage system which had originally been in fair accord with the structures, but as further examples of the phenomenon became known the hypothesis seemed increasingly inadequate, and H. J. O. White tentatively suggested that the rivers might have been superimposed from a tilted surface on which the folds had been completely planed off. In 1932 the writer attempted to apply this concept to the drainage of the whole Wessex region, but though the hypothesis seemed able to explain the anomalous features of the present rivers it was found necessary to assume that superimposition had taken place from a plane veneered by fluviatile gravels.

Since that date further investigation has revealed other and similar anomalous drainage features in Dorset and the Southern Weald which seem to demand a similar explanation. It has, moreover, proved possible to trace into the Wessex region the landform features, described in the preceding communication, which are inseparably connected with the Pliocene transgression. These permit us to believe that the Southern Weald and all Wessex as far west as a coastline which passed somewhat north-west of Basingstoke, Salisbury and Dorchester, was covered by the Pliocene sea, and that it was upon its emerged floor that the present streams arose.

The river systems are thus seen to afford a clue to the reconstruction of an episode which on the one hand provides an invaluable datum in problems of denudation chronology, and on the other can alone afford a rational basis for the geographer’s interpretation of the present landscape with its significant and striking regional contrasts. Finally, the new evidence enables us for the first time to perceive something of the importance of the Pliocene phase in the evolution of the landscape of south-eastern England as a whole.

Afternoon.

Tour of Nottingham.

Friday, September 3.

Presidential Address by Prof. C. B. Fawcett on The changing distribution of population (10.0).

Dr. Vaughan Cornish.—On the apparent enlargement of the setting sun (11.15).

The great increase in the apparent size of the sun when sufficiently near the horizon to be viewed together with the features of the landscape is a phenomenon which has attracted general attention throughout the ages. The customary explanation is that the largeness of the angle subtended by the disc is only fully appreciated when brought into comparison with terrestrial objects. It would not be unreasonable to inquire whether under
these conditions the sun should be magnified rather than the terrestrial features reduced in apparent size, but this question need not be raised for a different cause has been found, and verified by measurement.

The author has made a series of drawings in sketchbooks of uniform size of the sun’s disc in close proximity to the crest line of the Bernese Alps, as seen from very different distances. At the greater distances not only is the sun’s disc apparently enlarged but the apparent magnitude of the features of the mountainous skyline is enlarged (relatively to their increased distance) in about the same proportion. This was proved by comparison of sketches with the distances on the map. It was the practice of the author to include the whole field of attention, or conscious vision, in the page of the sketch book, and it was found that the arc of the horizon so comprised diminished with the increase of distance and that the exaggeration of each mountain peak was in the same proportion as the exaggeration of sun.

A singular but frequently verified fact attendant on these occurrences is the unconsciousness of any reduction in the angle of the field of attention.

The author has also found that the apparent enlargement of the setting sun is not confined to cases where the skyline is distant. Thus, the disc is often more enlarged when seen low down through the lattice of the branches of a neighbouring tree than when approaching the distant horizon of the sea. This is another instance of the unconscious narrowing of the field of attention when the amount of visual detail is increased.

Prof. P. M. Roxby.—The terrain of early Chinese civilisation (12.0).

1.—(1) The geographical factors affecting the rise of Chinese civilisation in the basin of the Yellow River with special reference to the validity of Mr. Arnold Toynbee’s contention that it affords a striking illustration of civilisation developing under the pressure of a ‘hard environment.’

(2) The relations of the North China Plain and the North-Western plateaux in the evolution of early Chinese civilisation.

(3) The relative importance of the intrinsic conditions of the terrain and of its geographical orientation as affecting the infiltration of cultural influences from the West.

2.—The distribution and character of the loess as a vital factor. The Northern and Southern limits. The extension of loess in a modified form into the central and higher portion of the Plain (Honan Water-parting) between the alluvial Hopeh Basin and the Hwai marshes.

The loess as a link between the Valleys of the Western plateaux and the isolated Shantung Highlands. The character of the loess as affecting the question of the existence of marshes and lakes in early times, and in relation to primitive agriculture. The views of Dr. U. K. Ting. The contrast of the Yellow River and Yang-tze Basins as terrains for early human development.

3.—Progress of knowledge, particularly through recent archaeological discoveries, as to the stages in the development of early Chinese civilisation and the relations between indigenous developments and external culture-contacts by way of the Kansu Corridor and Turkestan. Cardinal importance of a long West-East zone extending from Kansu through Northern Shensi (Wei-ho Valley) and Southern Shansi into Northern Honan and to the borders of the Shantung Highlands. Evidence for contrast in cultural characteristics prior to the establishment of the Shang Dynasty (2nd Mill. B.C.) between the Western (Kansu-Shensi) and the eastern (Honan-Shantung) portions of this zone. The eastern region claimed as the terrain of Middle and late Neolithic developments of a distinctively
Chinese character, particularly the li tripod and Black Pottery culture and as having been affected for only a short period by the Yang-Shao or Painted Pottery culture which almost certainly reached China from the West and was long characteristic of the Western or Kansu region, nearest to the source of origin. The Shang civilisation, as revealed by the Anyang excavations, had its centre on the western borders of the Plain, within the loess zone. Its culture undoubtedly composite, including elements which almost certainly reached it from the West, but yet seems in essence to have been a development of the late Neolithic civilisation of the Plain, incorporating all its characteristic features. While many conclusions must still be tentative, the view of Maspero and of many Chinese scholars that the Plain enclosed between lat. 31\(^\circ\) and 40\(^\circ\) N. and long. 113-118\(^\circ\) E. (and particularly the Honan-Shantung zone) was the nuclear area of Chinese culture has received considerable confirmation from recent discoveries.

There is also a case for considering North China as an important independent centre of early civilisation. This, however, does not minimise the significance of the Kansu-Shensi region both as the medium of cultural influences from the West and as the cradle of distinctive borderland organisations (e.g. the Chou) which later re-invigorated and assimilated the indigenous civilisation of the Plain.

**Afternoon.**

**Dr. H. C. K. Henderson.—Our changing agriculture as illustrated by central Derbyshire (2.0).**

While it is generally known that arable land in this country has suffered a decline, this paper endeavours to illustrate that the changes in agriculture in Derbyshire in the last 150 years are more striking than might be thought. The limestone area is shown as being to a very considerable extent under the plough at both dates for which accurate maps could be made, namely in the forties and seventies of last century. The records at both dates are incomplete, for varying reasons, but at least the Tithe Rolls of about 1840 illustrate that this limestone area was, as it is to-day, primarily a dairying region, and not a sheep-rearing district.

Each of the soil belts, from the Carboniferous Limestone to the Magnesian Limestone, shows a much greater amount of arable land at both dates than at the present time, while the Millstone Grits, though not at any time well cultivated, bore a much greater amount of woodland in the past.

The changes in agriculture reflecting industrial development include the decrease in waste land in the lead-mining areas on the Carboniferous Limestone, and also the great development of limestone quarrying in the western parts of this zone. The industrial region of the Coal Measures shows an increase in market gardening activities, and in the area of waste lands due to the growth of mining during this period.

**Mr. G. I. Smith.—The agricultural geography of Holland, Lincolnshire, with special reference to potato cultivation (2.45).**

Holland's chief surface materials are Post-glacial Silts, except in the south-west where Peats and Gravels of similar age are found. The Silts, which vary in texture from light sands to clays, give rise to soils which are equally variable, generally becoming heavier in a landward direction. The Peat soils also vary considerably but the small areas of Gravel give rise to fairly uniform sandy loams. Practically all Holland's soils, however, can be used economically for intensive arable cultivation.
The drainage system is efficient and the county is well served by road and rail transport. It possesses also a beet sugar factory and several fruit and vegetable canneries. Moreover, a predominantly agricultural and relatively dense population gives large reserves of efficient male and female labour.

Consequently, intensive types of arable farming, concentrating on specialised crops for distant markets and for industry, are characteristic of the county. The distributions of arable land and permanent pasture reflect especially soil conditions and, to a less extent, those of settlement and drainage. The distributions of the individual crops, of which the potato is almost everywhere the most important, reflect the same influences together with small climatic differences and certain economic factors. These minor factors, however, in the case of the potato, are sufficient to cause outstanding differences in the varieties grown and in the methods and rotations employed.

Mr. K. B. CUMBERLAND.—Livestock distribution in Craven (3.30).

The distinctive topography etched into the horizontal lower carboniferous strata of the Central Pennine Massif, together with the generally high altitude (300 to 2,300 ft.) and harsh climatic regime, impose serious restrictions upon the nature of the agricultural activities of Craven. The influence of these features is reflected in a peculiar land use, in livestock breeds and distributions, and in the seasonal activities of the pastoral village communities and livestock auction marts.

The marked differences in the types of pasture, associated with various altitudes and outcrops, results in one special feature of land utilisation, which is exemplified by a duplication of the 'moorland edge.' The sheep and cattle breeder of the Dales farms extensive acreages at low rentals, with a meagre return. His activities are limited in winter by an insufficiency of suitable pasture or fodder. He is consequently obliged to reduce his stock in autumn, and the resultant annual exodus of stock is the fundamental feature of the farm economy of Upper Airedale and Wharfedale.

To-day the dalesman's inability to improve the winter carrying-capacity of his farm, is largely economic. But, since attention has recently been attracted to the possibilities of hill grazings, Craven may experience a marked improvement in its grassland, particularly up to a general altitude of 600 to 700 ft.; although the limestone plateau surfaces present problems particularly their own.

Saturday, September 4.

Excursion to the Lower Trent.

Sunday, September 5.

Excursion to Derbyshire (Derby, Belper, Cromford, 'Via Gellia,' Grangemill, Rowsley, Matlock, Ripley).

Monday, September 6.

Joint Discussion with Section C (q.v.) on The potential mineral resources of Nottinghamshire and Lincolnshire, and their geographical significance (10.0).
Tuesday, September 7.

Mr. F. G. Morris.—The relations of history and geography as illustrated by the British colonies in America, 1607-1775 (10.0).

The British colonies in America offer a very fine field for the study of the relationship between history and geography, because in them we see the results of the transplanting of certain groups of European peoples, each with its own economic, social and cultural characteristics into a new natural environment, which had, however, already been modified by the Indians, to whom the Europeans were indebted in several ways. This new environment offered to the settlers certain possibilities, but the actual use made of them depended on the economic, social and cultural heritage of the different groups, together with the existing economic and political system of the British Empire. The broad division of the colonies into three groups—New England, Middle and Southern—may be admitted, the criteria being both physical and cultural. Nevertheless, in all these areas one should recognise sub-division into coastal and interior groups. Even within these more or less homogeneous areas, it is necessary to realise that settlers of different origin did not react in the same way to the same environment and that there were important contacts between them.


Charles Darwin lived in Downe House, Downe, from 1842 to 1882, and the house is now, by the gift of Sir Buckston Browne, in possession of the Association and is maintained as a national memorial open to the public. Close to Downe was also the residence of John Lubbock, afterwards Lord Avebury, Darwin’s friend and our President in 1881. Downe is hallowed ground for science.

Downe remains a rural village, though within the urban district of Orpington. It stands high (between 500 and 600 ft.) on the clay-with-flints which overlies the chalk of the North Downs. Its site is thus differentiated from most of the old villages in the district, which were established on other, less favourable, soils. It seems, on such slight evidence as has been found, that the village originated in clearings of the woodland for agricultural settlement from neighbouring communities. It paid tribute to the manor of Orpington. It is not mentioned in Domesday, and does not appear until later as a definite village community. The suggestion is made, therefore, that the original implication of its name is simply Orpington’s piece of downland.

Mr. S. J. Jones.—A prehistoric settlement phase in the Rio Grande Valley, New Mexico (11.30).

The area under consideration includes that portion of the Rio Grande valley bounded on the north-east by the Rio Grande Cañon and on the south-west by the White Rock Cañon, with north-westerly extensions along
the Rio Chama drainage and a south-easterly continuation into the Arroyo de Pecos. According to the archaeological work of H. P. Mera and the dendro-chronological studies of W. S. Stallings, the time concerned falls within the fourteenth, fifteenth and sixteenth centuries A.D. The main determinant of the settlements studied is a pottery development (Biscuit wares) characteristic of the whole area and indicative of a certain cultural and economic unity. The evidence suggests that Biscuit wares developed in a loosely knit assembly of settlements within a fairly well defined geographical unit—a unit small enough to produce a certain uniformity, large enough to permit local variations. It further suggests the temporary characterisation of a small geographical area within the larger framework of the agricultural peoples of the south-west.

Human occupation, based on the marginal cultivation of maize, beans and squash on the bottom lands, low terraces and alluvial fans, was rendered still more hazardous by the absence of domesticated animals and birds, with the exception of the dog and the turkey. Hunting and collecting are correspondingly important, although the former was limited in range and efficiency by the absence of the horse. Thus several early sites are near the junction of the piñon zone (piñon seeds) and the yellow pine zone (deer, bear, mountain sheep). Maps of the distribution of settlements at the close of the fourteenth, fifteenth and sixteenth centuries A.D. indicate the following sequence of events.

In the fourteenth century there were 56 comparatively small villages, but during the course of the century there was a general withdrawal from peripheral areas and a concentration upon the better terrace and bottom lands. Such concentration resulted in fewer but larger villages. Considerable shrinkage had taken place by the beginning of the seventeenth century, the number of villages having dwindled to 13. The reasons are difficult to assess. Coronado’s expedition had come and gone, leaving unsettled conditions in its wake; marauding nomads may have been exerting increasing pressure; between 1558 and 1593 there was an abundance of drought years, culminating in the particularly intense drought of 1579-85.

Mr. A. E. Smailes.—Population changes in the colliery districts of Northumberland and Durham since 1801 (12.15).

Based upon the parish returns of the Census Reports since the first Census (1801), a detailed study of population changes in these colliery districts, where coal-mining is the predominant occupation, reveals the process of mining colonisation and the characteristics of the population cycles of mining communities.

The history of settlement has been far from uniform over the coal-field, and has been characterised throughout its course by short-distance migrations from stagnating or declining to new or developing districts. After about 1830, moreover, many districts experienced large-scale immigration from outside: more recently, however, migration from the coal-field has been taking place, and in most districts the population is at present stationary or decreasing.

The marked regional variations which are indicated in the date of commencement of the industrial cycle, and in the number of cycles experienced and their relation to each other, are seen to be related ultimately to the geology as it affects the coal resources and their accessibility, to the distribution of different types of coal and the development of their respective markets, and to situation in relation to transport facilities.

They are in turn reflected in differences in the pattern and type of mining
settlement, and are important to an understanding of the differential trends of population at the present time.

Evening.

Joint Discussion with Sections C, D, F, K, M, on Planning the land of Britain (8.0). See page 486.

Chairman: The Rt. Hon. Lord Trent.


Wednesday, September 8.

Brig. M. N. Macleod.—Some recent work of the Ordnance Survey (9.45).

The Ordnance Survey offers the public a considerable choice in types of map, but the various types are not based upon any single plan. Modern teaching, research and economic planning demand not only several types of maps, but easy co-ordination of one type with the others. In this latter respect the Ordnance Survey range of maps could be improved. Large-scale plans are not published as a continuous series covering the whole country, nor is there direct connection of the small-scale maps with one another or of the small-scale series with the large. This leads to confusion of the layman and involves needless expense of publishing and buying.

The projection of large-scale surveys in separate county systems was in accordance with professional practice when the survey was started. By using a different system of projection it would now be possible to show the whole country with sufficient accuracy on a single projection system. The Cassini Projection and the Gauss Conformal Projection.

Attempts have been made at various times in the past to assimilate county surveys, but lack of a suitable triangulation system proved an insuperable obstacle. In 1935 a completely new system of triangulation was started which, when complete, will cover the whole country with a network of triangles of about four to five miles side and will provide data for assimilating all the large-scale surveys on to the same projections as are used for the small. The primary framework is well advanced, and once this has been adjusted it will be possible to take up the secondary triangulation in blocks.

For the assimilation of two 1/2,500 surveys on different projections tertiary triangulation would be necessary, giving a fixed point every mile, but this would be both difficult and costly. Research has therefore been undertaken to see whether it is possible to do tertiary triangulation with sufficient accuracy on air photographs. If this should prove successful the Department would have to initiate a comprehensive programme of air photography.

Mr. F. Walker.—The history of regional differences between south-west and south-east Lancashire (10.30).

The different characters of south-west and south-east Lancashire can be largely explained by their distinctive historical evolutions, which in turn
depend upon the permanent differences of physical conditions and orientation in south Lancashire and upon isolation formerly imposed by barriers of rivers, woodland and mosses.

These distinctions took different forms in different periods. Firstly, the extent of Roman, English and Norse settlement in the two areas depended largely on their orientation, while the greater prosperity of the south-west before the Industrial Revolution can be directly related to more favourable geographical conditions. Later the differences became more complex; thus, the religious differences between the strongly Roman Catholic south-west and the Protestant south-east and the economic divergence caused by the growing industry and commerce in the south-east were due partly to pre-existing differences and partly to historical circumstances. In this connection, moreover, the effects of personal factors and in particular the influence of a small group of powerful families in south-west Lancashire should not be overlooked.

Finally, these differences culminated in the distinctive parts played by the two areas in the civil strife of the seventeenth century and in the more obvious divergence which resulted from the Industrial Revolution.

Miss Alice Garnett.—Sunshine as a factor in the human geography of Alpine valleys.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Thursday, September 2.

Discussion on labour transference (10.0).

Mr. H. Wolfe, C.B., C.B.E.—Labour transference and the Ministry of Labour. (Read by Mr. H. L. Emmerson.)

The movement of workpeople from one district to another is no new thing, but whereas older movements were unregulated and doubtless to some extent misdirected, the Industrial Transference Scheme attempts, through the National Employment Exchange Service, to direct workpeople from the depressed areas into the places where they are most required and will have the best prospects. The depressed areas are given the first chance of filling suitable vacancies in other districts which cannot be filled locally and, further, the Ministry of Labour endeavours to anticipate suitable openings in developing areas and to arrange for selected workpeople from the depressed areas to come forward in readiness to fill them. The Ministry assists married men to remove their homes to new areas. Many men, inevitably, move on their own account, but these also may be assisted.

Juveniles are also assisted to move from areas of heavy unemployment and make a start in life elsewhere. The vacancies to which juveniles are transferred are carefully selected and must offer prospects of permanent and progressive employment. There are extensive arrangements for safeguarding the social and industrial welfare of juveniles transferred under the Ministry's auspices; lodgings are carefully supervised and hostels
have been established in certain areas where there is a shortage of suitable lodgings accommodation. Centres and summer camps have been opened to fit boys for transfer. Also, boys are trained for work on the land and sea, and boys and girls for work in hotels and private domestic service. Whole families may be assisted to move to areas where one or more of the younger members have secured employment.

A proportion of the adults and juveniles transferred inevitably return to their home areas, but very few families return, and the large and increasing number of families assisted to remove from the depressed areas represents a substantial contribution towards the solution of the problem they present.

Mr. S. R. Dennison (10.30).

Dr. O. A. Oesar.—Psychological and sociological aspects of labour transference (II.0).

Various public and private bodies are interested in the transfer of workers from distressed areas. In some places difficulties are met in persuading the workers to move, or to remain. It may, therefore, be instructive to consider some of the psychological and sociological problems involved in transfer. These are considered under three heads:

1. The condition of the material available for transfer.
   (a) Highly-skilled workers can more easily be transferred (provided they go to jobs for which their training is adequate) because:
      (i) Transfer from jobs of higher to those of lower skill is easier than the reverse—e.g. flax to jute, jute to canning.
      (ii) Such workers frequently have a tradition of emigration, e.g. to set up new machinery or factories in India, U.S.A., etc.
      (iii) They have a higher intelligence level and a wider knowledge, training and flexibility.
   (b) Unskilled labour is less flexible and on the economic level at which a family head gets more assistance than he could earn at present wage rates.
   (c) The type of educational system must be considered. Is it such as to make retraining (i.e. more learning) seem desirable to the worker.

2. The social and economic conditions of the areas between which transfer is to be made.
   (a) People can be moved from areas of lower to those of higher standards of living, e.g. Polish and Irish immigrations into Dundee.
   (b) 'Local patriotism' and reluctance to move: Scotland and 'The South.'
   (c) Traditions and subjective social status of occupations may act as blocks to incentive. Jute weaving v. spinning.
   (d) Areas having emigration pattern (Highlands, Cornwall) compared with those having immigration tradition (Dundee).

3. Condition and state of industries in the area compared with those of Great Britain as a whole.
   (a) State of jute industry and the growth of new social patterns among the unemployed.
   (b) An analysis of job changes in Dundee and the question of labour mobility between occupations.
   (c) Technological unemployment.
Mr. A. D. K. Owen.—The social consequences of industrial transference (11.30).

Industrial transference has important social consequences for (a) the community from which the transference takes place; (b) the community to which the transference takes place; and (c) the nation as a whole.

(a) For the community from which transference takes place the most obvious consequence is either a diminution in the rate of population growth or an actual fall in population. Transferees are for the most part single young men and women and comparatively young married men and their families, and their loss results in a cumulative ageing of the population. Examples from South Wales and Durham of the prospective effects of industrial transference on age structure. As transference is voluntary, there is also a selective process at work which tends to lower the average quality of the population. With some important exceptions, the more active and adventurous leave and the more conservative and unenterprising stay.

The proximate effect of transference is to reduce unemployment in areas from which it takes place, but the ultimate effect may very well be different. A distinction must be made between the effects of transferring unskilled workers and the effects of transferring skilled or potentially skilled workers. The denudation of an area of skilled labour impedes the development of new industries and may, in time, depress existing industries still further. In any case, transference presses hardly on secondary local industries by reducing aggregate purchasing power.

Local Government finance benefits from reduced pressure on the social services, especially public assistance, but many of the economies resulting from falling population are only slowly realised. Meanwhile there may be a heavy loss of rate income.

There are also losses in institutional life. Trade unions, churches, co-operative societies and other voluntary associations suffer the loss not only of financial support and membership, but of active leaders.

(b) For the community to which transference takes place there is a gain in population and an increased labour supply, largely free from trade union regulation, which provides the basis for industrial expansion.

Local Government has to provide additional social capital equipment in the form of houses, roads, schools, clinics and so on, but it receives an additional rate income as the number and value of its rateable properties increase.

There are, however, certain difficulties of assimilation and often a good deal of social friction as a result of the introduction of large numbers of new workers and their families into new areas.

(c) For the community as a whole, the greatest gain from industrial transference is the salvaging of large numbers of workers from the deterioration which results from long-continued unemployment. There may also be considerable economic gain as a result of the redistribution of labour supply in relation to employment opportunities. On the other hand, there is reason to believe that subsidised transference is artificially distorting the industrial structure of the country by disguising real costs of production.

It is also necessary to take into account the waste of social capital in the areas from which migration takes place and the increased social expenditure and disamenities of social life (such as road congestion, housing shortage, loss of open spaces) in expanding areas.

A new policy is urgently needed. Industrial transference should be continued, but along different lines. It should be related to a broad plan of national development in which both economic and social factors should be taken into account.
Friday, September 3.

Presidential Address by Prof. P. Sargant Florence on Economic research and industrial policy.

Mr. R. F. Harrod.—Business experience and economists' assumptions (11.30).

When rival and inconsistent theories compete for holding a given field, settlement should in principle be reached by an appeal to the facts. If the theories are logically coherent but lead to different results, there must be present in the premises one or more assumptions requiring empirical verification or disproof. Available statistical records, however, containing aggregate or average figures are often incapable of providing the required test, since it is usually possible to explain these in turn by suitable assumptions. What is the nature of these assumptions? In the last analysis it often appears that they are concerned with the way the individuals who go to make up the economic system, and particularly the entrepreneurs, behave in various circumstances. It is assumed, for instance, that when the market falls off entrepreneurs meet the situation by reducing prices and/or by reducing output in accordance with certain principles. But what principles?

The sheet-anchor of the economist is the principle that each entrepreneur endeavours in all circumstances to do the best for himself. By drawing certain curves supposed to represent demand, cost, etc., he can demonstrate what is the optimum position, that is, the position representing the procedure which will bring in the greatest possible profit currently and in the future, or, in other words, which will maximise the present value of the business. So far, no appeal to the facts seems necessary. It is needless to ask the entrepreneur what he will do in certain circumstances, since, if those circumstances are known, the economist already knows by reference to his guiding principle what the entrepreneur ought to do, and it is reasonable to suppose that he does that.

Unfortunately, the entrepreneur is often in a position when he is ignorant of many of the facts relevant to the decision to be determined, e.g. the future state of the market, or even the precise elasticity of demand as it is at present. An analysis will be made of various kinds and degrees of ignorance. Complete knowledge of all the relevant facts is hardly ever present. It may be necessary to exert judgment. Can this judgment be reduced to quantitative terms? e.g. can the entrepreneur, while ignorant of the precise value of a certain demand in future, none the less feel sure that it lies within such and such a range?

When placed in a situation of partial ignorance, how does the entrepreneur in fact behave? He has to decide something, even though full grounds for a perfectly rational decision are lacking. Furthermore, in the ordinary course of business it would be impossible to come to a separate decision, resulting from a separate act of judgment in every particular case, e.g. what price to charge for every particular consignment however small. Some rules of thumb are necessary. Is it possible to formulate these and to analyse them from the point of view of their economic soundness?
If the rules of thumb could be formulated, it might be found that they contained some definite bias, e.g. leading in certain types of situation to over-production or under-production compared with that resulting from a random choice within the range of ignorance. This bias might be due to certain considerations of convenience in the formation of the rules of thumb, e.g. simplicity, tradition (in an old firm traditional rules may be sponsored by past success, yet none the less be unsuitable in a new environment), and even quasi-ethical considerations. This bias may be important in the explanation of the sequence of events in a trade cycle.

It is often assumed that competition leads to the survival of the most efficient. Efficiency is thought of in terms of intelligence, accuracy, punctuality, etc. It may be that the survival of firms occurs in a somewhat different way, more analogous to Natural Selection in biological survival. Where ignorance is great, the exercise of choice based on pure reason may be much circumscribed, firms may exhibit random variation in their rules of thumb, and those which throw up successful rules be selected. This success may not be the result of intelligence, since in the circumstances intelligence would be unable to say which rule of thumb is best.

Possible modes of operation of these principles will be explained with special reference to the treatment of overhead costs.

A group of Oxford economists interested in the Trade Cycle has recently instituted an inquiry, with the object of eliciting certain matters of fact with regard to business behaviour relevant to the determination of disputed points in trade cycle theory. Entrepreneurs have been interviewed by the group as a whole and by individual members of it, and have been subjected to intensive interrogation with regard to their normal behaviour in certain defined circumstances. While the question of what general conclusions emerge from these inquiries is still sub judice, and details cannot be given, something will be said about the light thrown by them on the general questions outlined above.

**Afternoon.**

Sir Wm. Beveridge, K.C.B.—The co-operation of business men in the advancement of economics (2.45).

Prof. Z. C. Dickinson.—The co-operation of business men in economic research in U.S.A. (3.15).

**Monday, September 6.**

Discussion on Retail distribution (10.0).

Prof. A. Plant.—The scope for operating cost comparisons and their limitations.

A signal example of collaboration for the comparison of operating expenses has been furnished for the whole distributing trade, and indeed for carefully selected groups of industrial firms, by over one hundred of the department stores of Great Britain, which regularly, for the last six years, have pooled their annual operating returns upon an agreed schedule of carefully defined costs issued by the Retail Distributors Association. The method used has two essential characteristics which are worthy of wider adoption. The handling of the returns, the devising of methods for utilising them, and the
compilation of reports for circulation among the collaborators is performed by members of a University staff at the Department of Business Administration in the London School of Economics. That ensures complete detachment from the collaborating firms and from any trade association. Secondly, the coding of returns which are sent through the office of the statistical department of the Bank of England ensures complete anonymity, while limitations of the group to firms receiving specific invitation to collaborate secures selectivity, and ensures a usefully comparable sample. The handling of the returns inevitably involves statistical problems due, for instance, to a changing sample from year to year and to the difficulty of relating income and expenditure figures to valuation of capital. Arbitrary decisions must be taken for dealing with such matters as rental of owned premises, but these problems may be overcome by methods which do not invalidate the results.

For the most effective use to be made of the results it is necessary that there shall be a wise exercise of discretion by the computers. Averaged figures must frequently be accompanied by measurements of dispersion if erroneous impressions are to be avoided, and new statistical methods must continually be devised to give appropriate emphasis to changes in trading conditions. There must also be a proper understanding of the reports in each of the collaborating firms if full use is to be made of the results. This involves in many cases the appointment of staff with special training.

The justification for comparing operating costs in this way lies in the revelation of significant differences. To be significant they must be differences in the cost of undertaking broadly similar functions, so that homogeneity of sample is all-important. Because differences in costs must be expected between similar firms performing similar functions in different situations, no special significance must be attached to average figures; the collaborating firms must regard them as landmarks, not as signposts. They raise questions rather than propose solutions; 'goal' figures for particular cost items are consequently to be deprecated. Further, there is no fixed constellation of differences in costs likely to endure over time. Trading conditions are not static and changes in costs with changes in sales are all-important. Cost studies must therefore concentrate upon the rates of change in costs which are associated with given rates of change in sales. Operating cost studies become marginal studies. There is a steadily growing need for associated annual studies in other branches of business, particularly in the field of distribution, on the pioneer lines of British department stores.

Prof. B. F. Shields.—The Irish census of distribution (10.30).

An examination of reports of the Tribunal on Prices, 1927, and Commission on the Registration of Shops, 1934, with respect to retailers' costs, excessive prices, redundancy, registration and licensing of shops.


Irish Census of Distribution: objects, scope, procedure, general analysis and limitations of the inquiry. Comparison with other government censuses. Expenditure of retail £. Investigation of human element in retail distribution: family, proprietors, employees, males, females. Wages and salaries, as a whole, in grouped firms, and areas in relation to businesses of varying size, and as a percentage of sales—the larger the turnover, the higher the total wages as a percentage of sales? Single and multiple shops,
owned and not owned in the Saorstat. Rate of stock turnover per annum in various businesses in different areas and according to the size of business. Analysis of returns for large size businesses. Duration of ‘ownership’ of retail shops. Predominant position of Dublin in retail trade.

Mr. H. T. Weeks.—*The trial census of distribution (II.0).*

The Trial Census of Distribution was designed to show how valuable a complete census on wider lines would be. Field investigators covered six towns of equal size and by inspection recorded the trade description of each selling outlet, the products sold, whether the shop was a branch of a multiple or co-operative, whether a lock-up or house shop. In an official census information on total turnover could be obtained, and possibly turnover of commodity groups, but since such information could not be obtained in this unofficial inquiry rateable value was added to serve as an illustration of (but not a substitute for) turnover figures.

The results of the census showed surprising variety between the six towns in most trades. There were extreme differences in the numbers of outlets for many important products, and evidence of a different growth in the distributive system which could only be guessed at from other statistics.

The Trial Census was frankly propaganda to prove to businesses in distribution that a census would be valuable. Specifically it would help in fixing sales quotas, guiding local sales drives, and determining development policy, and the four sponsoring firms contributed notes on how they would use the material from the Trial Census.

But the Trial Census has more than a purely commercial interest. It suggests that if control is necessary in distribution, existing statistics are insufficient and previous measurement by census is essential. It shows that a Census of Distribution would be essential to distributors, to administrators and to theorists on distribution.

Mr. H. G. Selfridge, Jun.—*Consumers’ control and the expenses of distribution (II.15).*

It is a pity that an item of merchandise in a customer’s home is called by the same name as is the same item in the manufacturer’s warehouse, because that tends to hide the exceedingly important economic fact that the intervening processes through which it has to pass are somewhat similar in quality, and generally at least as expensive, as the processes that make the finished item out of its constituent raw materials.

Prof. Plant has described the methods by which we have obtained very satisfactorily accurate figures as to what those processes of distribution cost. Allowing for a reasonable and necessary net profit, they cost just over 30 per cent. of what the customer pays for all she buys in department stores and similar shops.

An analysis of the processes shows how complicated is the function of the distributor. The most important difference between what he and what the manufacturer does lies in the fact that the distributor’s customer is an individual with very individualised wants, an individual, furthermore, who is entitled to and does ignore those considerations that business training and experience might tell her should decide how those wants are to be satisfied. Whatever the distributor does, is fundamentally at the behest of his customer, whose money, indeed, pays for the whole of his activity. That the
customer does pay for it is a free bargain, for she retains the right to undertake his work for herself if she wants to—or can refuse to buy altogether.

There is a school of opinion growing up, that what the distributor does should be rationalised. It is an attractive view, because without a doubt there is a great deal of what the economist is justified in calling waste, in distribution. Detail processes are all the time being improved with the elimination of waste and expense. But the main source of what this school of opinion complains of, lies in the insistence by the customer that her sometimes irrational wants should be satisfied. This source of complaint can be removed only by rationalising the customer. It is definitely not the function of the distributor to do that, whatever his personal views may be; but a distributive industry already provides many opportunities for the self-rationalised customer to save money if she really chooses to exercise them.

**General Discussion on Retail distribution (11.45).**

**Afternoon.**

Visit to Castle Tobacco Factory, Messrs. John Player & Sons.

**Tuesday, September 7.**

Prof. H. A. Innis.—Significant factors in Canadian development (10.0).

The economic development of the United States was hastened by the absence of restrictive institutions such as an established church and an official class, and by the preoccupation of a large rural population with business, the neglect of leisure, and the character of democratic institutions. In Canada, the importance of water transportation and the consequent emphasis on staple exports shown in the fishing industry, fur, timber, wheat and minerals in relation to a European market provided a background in which an established church, military organisations and the official classes occupied an important place. The fur trade during the French and English regimes accentuated the importance of regimented control evident in the position of the Church, the army and the governing class. The timber trade emerged from a background of imperial preferences under the colonial system. Government ownership has been conspicuous in the period dominated by wheat, minerals, and pulp and paper, and their demands for steam transportation and hydro-electric power. The paper attempts to trace the significance of institutions in the economic development of Canada.

Prof. H. Hermann Levy.—Death benefit and industrial assurance, or the cost of dying (11.0).

Industrial assurance is mainly a provision for funeral money among the working classes. Death benefit in history: in the days of the gilds, craft gilds and corporation. Death benefit and the era of capitalism. Friendly Societies and Trade Unions no effective instrument. The rise of industrial assurance companies and friendly collecting societies. Their deficiencies as stated by Mr. Gladstone, the Northcote Commission, the Passfield-Parmoor and Cohen Reports. Legal reforms. Present evils: the system of canvassing, payment of agents by commission and pressure for increase;
solicitation of and pressure on prospects; the evil of lapses; the gambling element. Reform needed. Different proposals: Public Utility Corporation; inclusion into the National Health Scheme as originally planned; methods of Germany, Japan and other countries. Difficulties of reforming industrial assurance merely by new legal enactments and a widening of the powers of the Industrial Assurance Commissioner. Effective reforms must be accompanied by a cheapening of funerals and burial in general. A problem of wide economic and sociological importance not soluble without drastic changes in traditional habits, customs and ethical conceptions.

Mr. S. R. Dennison.—The State control of industrial location (12.0).

The continuance of localised depression has resulted in proposals to subject location in State control. The need for this depends upon the possibilities of spontaneous re-adjustment in the areas concerned; it appears, however, that neither of the two possible lines of re-adjustment, the development of new industries and transfer of workers, is likely to solve the problem completely.

An intermediate stage is the provision of various inducements to industrialists to establish their plants in depressed areas. Those which have been proposed involve certain difficulties and implications, and it is not certain whether they would be effective.

The primary decision which is necessary is whether a policy which has important long-run effects, involving changes in the whole industrial structure of the country, is appropriate for dealing with a short-run problem. The appropriateness of control further depends upon a balancing of cost against gain. The former could result from a loss in industrial efficiency; the latter would be derived from alleviation of localised unemployment and some saving in capital construction.

Control would involve certain practical difficulties; these would vary according to the type and degree of control imposed. It would further have certain important implications for the economic system as a whole.

Afternoon.

Visit to works of Messrs. Birkin & Co.

Evening.

Joint Discussion, with Sections C, D, E, K, M, on Planning the land of Britain (8.0). See page 486.

Wednesday, September 8.

Mr. J. D. Chambers.—The position of the occupying owners in Lindsey in the period 1780–1830 on the basis of the land tax assessment returns (10.0).

It has lately been shown that the small freeholder who also occupied as well as owned his land did not decline but, on the contrary, increased in numbers during the period when enclosure was taking place most rapidly, e.g. 1780–1830. But no attempt has yet been made to ascertain the rate of increase of the different categories of peasants, and at what point it reached its maximum. Also, the cause of the increase is still unknown. The present inquiry attempts to throw light on both these questions.
A number of villages in Lindsey have been examined on the basis of the Land Tax Assessment Returns, and the results correlated with enclosure history and with the conditions of farming during the period. The paper brings out the importance of statistical evidence in making historical generalisations regarding the behaviour of a social group.

A further point in regard to the paper is that the material has been wholly collected by adult students—members of the Lindsey Local History Society and by adult classes. They have given their Saturday mornings, and in several cases their holidays, to the work. It is an example of group research which will be continued in Lindsey and probably in other parts of the area.

Mr. T. H. Silcock.—Some aspects of retail price maintenance (11.15).

The Retail Market.—Difficulty of applying the ordinary theory of choice. The buying habits of the ultimate consumer. The relation between his long-period and short-period plans. Limitation of the field of consciousness at any one time. The mechanism of impulse and 'sales resistance.'

The Manufacturer and Retail Price Maintenance.—The aim of the manufacturer is to secure maximum profits and continuity. The importance of volume of sales. The effects of Retail Price Maintenance on the volume of sales; meaning of consumer's confidence and conditions in which it could offset higher prices; meaning of retailers' support and conditions in which it is worth securing; effects on the number of retail outlets; advantages of widespread distribution; complementary goods and their effect on retail stocks. Dangers from incomplete price maintenance. The power to maintain prices may only be available to those who limit the number of outlets.

The Retailer and Retail Price Maintenance.—Tendencies toward normal profits in retail trade. Competition between different lines. Profit per unit of general cost of operation, and the importance of elasticity of demand. Short-period effects of advertising lead to a need for price maintenance. Long-period effects on turnover; the demand for a limitation of the number of shops. Special difficulties arising from co-operative societies and price maintenance.

The Public and Retail Price Maintenance.—Consumers' choice and the position of the economist. Difficulties arising from advertising and discrimination. The need for conscious choice by the public in this sphere. The short-period and long-period effects of price maintenance on prices and on the size of firms.

Possibilities of Policy.—Contracts and combinations to maintain prices; the position of patented articles and of trade-marked articles. Risks of Government or municipal control without more intelligent public opinion. Risks of diminishing the present powers of firms to maintain prices. Need for wider knowledge.
SECTION G.—ENGINEERING.

Thursday, September 2.


Mr. E. H. Bateman.—The analysis of elastic structure by the methods of deformation-energy and remainder distribution (12.0).

Systems of analysis referred to by various writers as the methods of Virtual Velocities, Stationary Potential and Least Work are known as being well suited for the solution of problems in rigid mechanics, and corresponding methods based on Maxwell’s Reciprocal Theorem have been developed for application to Elastic Structures. These methods, often described generically as strain energy methods of analysis, have hitherto been applied in terms of forces or stresses, while little attention has been given to the alternative application in terms of deformations, which the author has proposed to designate the method of Deformation-Energy.

This method is applicable to structures which are statically determinate or statically indeterminate; in cases of the latter class it may lead to simpler forms of analysis than other methods, because the number of indeterminate deformations may be less than the number of indeterminate forces or stresses, and also because it may be easier to specify the possible deformations of a structure than to ascertain a convenient system of independent indeterminate forces.

The paper includes a short account of the author’s method of Remainder-Distribution for solving the simultaneous equations which result from the application of strain energy methods of analysis to a statically indeterminate structure. The method is illustrated by a solution of the problem of a continuous girder on elastic supports.

AFTERNOON.

Visit to R.A.F. College, Cranwell.

Friday, September 3.

Discussion on The training of university graduates for the engineering industry (10.0).

Prof. F. G. Baily.—Introduction.

Mr. A. P. M. Fleming and Dr. W. Jackson.

The authors stress the need for a more effective co-ordination of the resources of the Universities and of industry than is at present the case. The engineering departments of the Universities should not be required to provide instruction in workshop practice, machine design, industrial administration and in specialised technological subjects, but should concentrate on teaching a sound knowledge of the properties of engineering
materials and of the scientific principles involved in their application. Too little opportunity is given in present-day engineering courses for independent reading and thinking, and for humane studies. Industrial concerns must do more than provide opportunities for practical training—they should undertake, both independently and in co-operation with adjacent technical colleges, the necessary instruction in the aforementioned subjects. Wherever possible this instruction ought to be given during works hours. Such provision is possible only with large organisations, and on these rests the responsibility for training men for the country as a whole. A brief description is given of an existing apprenticeship scheme of post-graduate training which conforms in some measure to these requirements.

It is very necessary that the engineering departments at the Universities should undertake fundamental research work in co-operation with the physics, chemistry and metallurgical departments on border-line subjects of industrial importance. Scholarship provisions enabling men of outstanding ability to return to the Universities for one or two years after some experience of industrial work would stimulate this activity and react very beneficially on industrial development. Industry might with advantage afford facilities in its research laboratories for members of University staffs to carry out, and where possible to supervise supplementary work beyond the scope of the financial resources of the Universities.

**Afternoon.**

Lecture and demonstration by Mr. W. H. Haile on *The engineering problems of the River Trent Catchment Board* (2.30).


**Saturday, September 4.**

Excursion to North Derbyshire (Staveley, Lady Bower Dam, Gliding Competition).

**Monday, September 6.**

Dr. Oscar Faber, O.B.E.—*Some aspects of heating and air conditioning* (10.0).

The author explains that air conditioning involves the increase or the decrease of both temperature and humidity, and that filtration is in many cases also necessary. He describes the conditions which are usually accepted as necessary for comfort and he discusses the relative merits of alternative systems adopted for each process.

He makes special reference to the recent installations in the Bank of England and in the Queens Hotel at Leeds. He refers also to the special difficulties encountered in large cinemas and in buildings in the tropics.

Mr. A. Swan.—*Problems of the altitude record flight* (11.0).

As the atmospheric density decreases with increase of height it follows that, for a given true speed of flight, the greater the height, the smaller is the resistance to the passage of an aeroplane. This makes flight at very high altitudes attractive so far as high speed and economy of time and fuel are concerned.
There are, however, many problems to be overcome before flight in the stratosphere becomes commonplace, and such attempts as the altitude record flight are of considerable value in determining how far the inherent difficulties may be overcome. These problems include the provision of a power unit which will retain sufficient power to enable the aeroplane to reach the desired altitude, the special design of an aeroplane of adequate wing surface and suitable aspect ratio, and supplying the occupants with a sufficiency of oxygen.

The paper deals with the altitude record flight of 53,937 ft. by Flight-Lieutenant M. J. Adam on June 30, 1937, in a Bristol aeroplane powered with a Bristol engine and flown from the aerodrome at the Royal Aircraft Establishment, Farnborough, and outlines the factors governing the choice of type of power plant, the design of the aeroplane and airscrew, and the provision of a pressure suit for the pilot. A brief résumé of the pilot's report on the actual flight is also included.

Prof. H. W. Swift and Dr. H. L. Haslegrave.—Experiments on sleeve bearing lubrication (12.0).

This paper deals with experimental work on a sleeve bearing 4 inches diameter by 12 inches axial width under loads up to 10,000 lb. and at speeds up to 1,200 r.p.m.

The apparatus is described in detail, its calibration and behaviour are discussed, and results are given of tests made with an entry angle of 90°.

The bearing was loaded upwards by means of a letter-balance, lever and dead weight system. Friction was measured separately on the bearing and on the journal. Shaft displacements were determined from micrometer measurements at both ends of the bearing. Oil pressures were measured at thirty-two representative points on the bearing surface by means of Bourdon gauges.

The results obtained are in general conformity with theoretical expectations though certain systematic discrepancies are evident which are attributed to a tendency to vibration at light loads and to the difficulty of measuring the oil temperature in the film.

Afternoon.
Visits to L.M. & S. Railway Research Station, Derby; Bar-lock Factory; North Wilford Power Station; Stanton Ironworks.

Tuesday, September 7.

Prof. E. W. Marchant.—Electrical vibrations and their applications in television (10.0).

A description is given of the methods used for producing electrical vibrations of various kinds. The dynatron oscillator is illustrated by a water model with a valve having a controlling force which diminishes as the valve opens. Such an arrangement, with a U tube connected across it, illustrates the principle of action of this oscillator, the oscillation being demonstrated by the movement of the water in the U tube. The principle of the thyratron controlled 'time base' for a cathode ray oscillograph or television receiver is also illustrated by a water model. The capacity of the condenser in the circuit giving the time base is represented by a small pivoted vessel so arranged that when it fills it tilts over and empties itself. The flow of
water into the vessel is kept constant, as is the electric current which charges the condenser used in the time base, and the 'grid bias' of the thyatron is represented by a pivoted arm which prevents the tilting over of the vessel until it has filled to a definite level. The height to which the vessel must fill before tilting over is controlled by a weight on the pivoted arm. Reference is also made to the vibrations used in one form of camera. The angular velocity of a free electron rotating in a magnetic field is equal to 

\[ \frac{Be}{m}, \]

where \( B \) is the strength of the field and \( e \) and \( m \) are the charge and mass respectively of the electron, and is independent of its initial speed. The arrangements for focussing the photo-electric image so as to produce the necessary photo-electric currents for television transmission are explained, and also the need for using short waves and the corresponding limit of distance to which television transmissions can be sent.

Mr. L. H. Pomeroy.—The design of motor vehicles in the interest of traffic safety (11 o).

The paper starts by referring to the degree of concentration called for from motorists to avoid accidents, and deals with design features to reduce motoring fatigue.

It mentions necessary standards of performance to reduce dangerous traffic congestion, but regards ultra high maximum speed as unessential. Dealing with cars as a whole, it treats body design features as of primary importance which chassis designers must regard as a condition of design. Body design is discussed in terms of visibility, correct driver's seating position, and suggests that modern streamline body design has been at the expense of the amenities of driver and passenger.

Reference is made to the modern 'all seats between the axles' motif, and the mechanical and artistic sacrifices thus entailed.

Chassis design is dealt with in terms of acceleration and braking, with reference to the allied problems in steering and suspension. The importance of silent operation is emphasised and the causes of the noises arising from engines, gears, chassis and body, indicated and discussed.

The principles of safe driving are mentioned, together with the special difficulties of night driving.

The paper concludes with a reference to the great work done by engineers and manufacturers in making cars which can be safely driven, and suggests that comparable study and action is called for from Road Authorities and the non-motoring public in the interests of road safety in general.

Mr. E. G. Herbert.—A continuous hardness test (12 o).

The new continuous hardness test produces automatically a permanent record of hardness changes occurring in metals during a period of ageing. The basis of the test is a scratch or groove formed by a loaded grooving tool in a specimen slowly traversed under it by clockwork. The ageing period investigated is usually one of 48 or 60 hours, but the period can be extended to as many days or weeks as may be desired.

The usual type of scratch test with angular or pointed scratching tools having been found unsuitable for exhibiting ageing changes, a new test is introduced in which a groove is rolled in the specimen by a rotating steel ball. This test is shown to be susceptible to changes of hardness due to work-hardenning and age-hardening.
Variations of hardness are shown by varying dimensions (depth and width) of the groove. The depth can be autographically recorded on a drum covered with photographic paper. Alternatively, the groove is 'scanned' by optically projecting it at a high magnification and measuring its width at intervals corresponding with a time scale mounted alongside. The width is readily converted into Brinell hardness.

The continuous hardness test is used to investigate periodic fluctuations of hardness following magnetic or thermal disturbance of the metal, and for recording age-hardening effects.

The periodic fluctuations are attributed to electromagnetic pulsations in the atomic structure of the metal.

AFTERNOON.


Wednesday, September 8.

Dr. L. G. A. Sims.—Specification of the A.C. method in permeability measurement (10.0).

The paper first records the formation of a B.S.I. Committee to standardise measurements of incremental magnetic quantities, particularly incremental permeability. This step is a direct outcome of the support given by the British Association to the writer's papers at Norwich in 1935 and at Blackpool in 1936, and to the co-operation of the British Standards Institution. The paper then provides a brief outline of the new committee's work to date, but its main purpose is to direct attention to certain difficult matters with which the committee will have to deal in the future. Amongst these are the following: First the definition of a distortion factor, which raises the question of the suitability of form factor as a criterion of wave purity, various alternatives being proposed. Secondly it is pointed out that appropriate nomenclature together with a scheme of symbols urgently require consideration. Thirdly the graphical form in which results may best be presented to industry is discussed. The first two of these, at least, are of international interest and importance and examples are given in the paper of lines along which solutions may be reached.

Mr. Jas. Greig and Mr. J. E. Parton.—Flux distortion in iron testing.

SECTION H.—ANTHROPOLOGY.

Thursday, September 2.

Mr. A. L. Armstrong.—Palæolithic man in Nottinghamshire (10.0).

Disregarding various Eololiths found in the terrace gravels of the Trent Valley, the earliest definite evidence of man's presence in the county is provided by artifacts of late Acheulian type contained in the gravel of the second terrace of the Trent in the neighbourhood of Beeston, to which attention was first called in 1928. Abundant evidence of occupation during Mousterian times has been provided by the Creswell cave excavations; also
throughout Upper Palæolithic times. The excavation of two rock shelters, carried out in the present year, at Whalley and Creswell, are described, both of which have confirmed the evidence obtained in the Creswell caves that man continued to dwell in this region throughout the final glaciation and occupied the rock shelters until early Mesolithic times.

Mr. H. J. H. Drummond and Mr. T. T. Paterson.—Recent Palæolithic discoveries in India (10.35).

   The Soan Culture, extending throughout the II Interglacial and III Glacial periods, comprises flake and pebble tools, the latter predominating in the Early Soan, the former in the Late Soan. The flakes and cores are at first reminiscent of the Clactonian, but in the Late Soan many of them are distinctly Levalloisian in technique. Acheulian coups-de-poing are found at a few sites, at one of which Late Acheul is in contact with Late Soan.

2. Sind.
   At Rohri and Sukkur, on the Indus, there have been found enormous quantities of flint flakes, blades and cores, mostly surface finds. Among the cores are many large Landaxe-like forms, some of which have been retouched to form regular coups-de-poing. In date these are probably contemporary with the earliest stages of the Mohenjo-Daro civilisation, though some of the finds from Sukkur, including many thick crude blades, are more patinated than the others and are undoubtedly slightly older.

3. Madras.
   Numerous Palæolithic finds have been made in many parts of Madras Presidency, on which work is still being carried out. The Abbevillian-Acheulian cultures are widespread, Upper Acheulian, with many South African affinities, being especially common. Some localised flake industries of Upper Acheulian or later date have been found, but as yet no typical Upper Palæolithic culture has been recognised.

Mr. J. G. D. Clark.—New discoveries relating to the earliest settlement of northern Europe (11.10).

This paper is intended to draw attention to a method of excavation which has done much to advance our knowledge of early cultures in N.W. Europe, and of the environment in which they flourished and had their being.

The method consists essentially in the investigation of settlement sites placed in immediate proximity to geological deposits of recent age, and in the establishment by means of careful sections of a relationship between debris and 'scatter' from the settlement and the succession of deposits with their contained flora and fauna.

From the use of such a method the following results have been obtained:
   (1) Objects of perishable materials have been recovered to supplement cultures previously represented only by flints and stone implements.
   (2) Climatic and vegetational conditions contemporary with prehistoric sites have been reconstructed.
   (3) A chronological succession of cultures has been obtained: (a) by direct superimposition; (b) by reference to the local sequence of natural events.

Outstanding examples can be cited from East Anglia (Fen sequence),
the Hamburg area (Ahrensburg and Hamburg cultures), Central Jutland (Gudenaal culture), and N. Esthonia (Kunda).

Mr. J. N. L. Myres.—The ceramic evidence for the Anglo-Saxon conquest (11.45).

The ceramic evidence for the Anglo-Saxon conquest consists mainly of material recovered, often under unsatisfactory conditions, from cemeteries. Even so, it may be expected to throw light on the date of the invasions, the continental provenance of the invaders, and the character and extent of their settlement in England. Direct evidence from datable finds for the earliest settlements is very scanty, but is not inconsistent with the traditional stories of a mid-fifth century Adventus Saxonum: if this is so, however, a downward revision of the dating usually used for some types of the corresponding continental pottery may become necessary. The continental connections of the English pottery are with that found in the Angle, Saxon, Frisian and Rhenish districts, and it will be urged that Bede unduly simplified both the tribal complexity of the invaders and their geographical distribution in England. The information provided by the pottery not only on the burial customs of the invaders, but also on their social habits, the relationship between different areas, and their association with the surviving natives is discussed, and the significance of the use of stamped ornament in this connection is illustrated.

Mr. Kenneth Jackson.—The Anglo-Saxon invasion in the light of early Welsh poetry (12.20).

The very early Welsh poem called the Gododdin purports to belong to the late sixth century, and to give a contemporary account of hostilities between the Britons of the Edinburgh district and the invading Northumbrian Angles at that time. If this is true, it is obviously a very important historical source, but it has been almost entirely ignored by writers of the modern archaeological school. What the poem tells us. The text can be traced back with certainty to the ninth century; the probability is that the Gododdin is actually as old as it claims to be.

Mr. J. Butter.—A Palaeolithic horizon in Holland (12.45).


In 1935 Van Gendt, the Director of Public Works, being in need of sand for making a sports ground, began excavations at Deventer. The digging extended from about 5½ m. above sea-level to 2½ m. below sea-level.

The first thing found (at 0·67 m. above sea-level) was a kind of paddle or side rudder as used in Viking ships (cf. Lefèbvre des Noettes, De la marine antique à la marine moderne, 1935, figs. 42, 64, 65, 68). This was made of wood, and was presented to the Waag Museum. At the same level there were discovered some 2,400 human and animal bones and other objects.

Below this level there were four layers of gravel, the second of which contained a layer of clay. In the second and third layers were found modern and rolled Miocene shells, bones of Equus, Bos, Cervus, etc., horns of Cervus elaphus worked by men, long bones of men, a hammer-axe, and a point with haft, etc. (Maglemose or probably later). Under the third layer of gravel there was first brown sand with Clausilia dubia, Pupa, etc., then grey sand and a skull with a ‘chignon’ like the Cro-Magnon.
Somewhat lower under the same layer was found a fragment of a skull and a third skull which lay about a metre from a tree; a part of this tree has been sent to the Institut de Paléontologie Humaine at Paris for determination. In the fourth layer of gravel were found tusks of *Rhinoceros tichorhinus*, molars and humerus of *Elephas primigenius* and *Bos primigenius*, parts of the heads of *Cervus megaceros* and *Sus scrofa*.

The determination of the bones was done by Prof. Abbé H. Breuil, Prof. Vaufrey, Dr. Tindell Hopwood, and somewhat later by Prof. Dr. G. Hasse.

**AFTERNOON.**

Prof. W. W. Jervis and Mr. S. J. Jones.—*An anthropometric survey of Somerset (2.15).*

The area investigated lies between rivers Avon and Parret, including the Mendips, the Poldens and the moors drained by the Kenn, Yeo, Axe, Brue and Parret: 73 villages have been studied and 400 adults have been measured. Relevant data from the *Beddoo MSS.* in the University of Bristol Library have been used for comparative purposes.

The graph of stature for men shows a peak of 5 ft. 6 in. (17·65 per cent.) and a secondary peak of 5 ft. 4 in. (10·08 per cent.) ; that for women has two equal peaks (16·67 per cent.) at 5 ft. 2 in. and 5 ft. 4 in. Short stature and a considerable degree of pigmentation (hair and eyes) seem more closely associated in women than in men.

Of the total cases, 43·5 per cent. have brown hair, 30·5 per cent. dark brown and black hair, and 26 per cent. light hair (lighter than brown). In this respect there are no marked differences between the sexes; thus 29·7 per cent. of the men and 32·5 per cent. of the women have dark hair (including brown). Contrasted with this, 26·4 per cent. of the men and 43·4 per cent. of the women have well pigmented eyes (hazel, brown). This may support the view that eye pigment changes more slowly than hair pigment.

The head index graph for the whole group shows one peak at 77 (18·29 per cent.) and a secondary peak at 80 (13·57 per cent.). 67·5 per cent. of the cases lie between these figures (inclusive). In the dark groups (brown-black hair, pigmented eyes) 19·5 per cent. of the women and only 8·6 per cent. of the men are dolichocephalic. In the fair group (hair lighter than brown, unpigmented eyes) 48·1 per cent. of the women have a head index of 80 or over. With this is associated a marked tendency towards narrow jaws or a ‘pinching in’ of the lower part of the face, throwing into higher relief the cheek bones and zygomatic arches.

These and other results are discussed in the paper.

Dr. G. M. Morant.—*The Anglo-Saxon population of England (2.50).*

The best descriptive material available relating to the Anglo-Saxon people consists of measurements and cranial tracings of skeletons preserved in a number of English museums. In recent years these have been treated in papers by Morant (1926), Parsons (1928), Brash, Layard and Young (1935) and Münter (1936). The last deals with lengths of the long bones only, and the present communication presents the chief results of a survey of additional crania carried out by the same writer. Including the earlier records, it deals with the measurements of nearly 700 adult skulls and the contours of 300. Topics discussed are a comparison of the measurements taken by different observers, constants for different sub-groups of the total sample, sexual comparisons, and the variabilities of regional sub-groups.
(Angles, West Saxons, East Saxons and Jutes) and of the total series compared with those for other series. The Anglo-Saxon type is compared with other British ones of different periods. The distinction previously observed between the Anglo-Saxon and all later English populations for which adequate cranial data are available is confirmed, and illustrated by average measurements (including values for lower jaws) and type contours. Comparisons with continental material show that the Anglo-Saxon type bears a closer resemblance to that of the Row-Grave people than to any other known.

Mr. J. C. Trevor.—Some anthropological characteristics of populations derived from the crossing of distinct ethnic groups (3.30).

This paper forms part of an investigation into the social and biological effects of race crossing at present being undertaken by the writer, who holds the Eugenics Society’s second Leonard Darwin Research Studentship at the Galton Laboratory, University College, London.

The anthropometric characters of a number of series representative of living groups of mixed descent from various parts of the world are considered. It is found in every case that for characters which clearly distinguish the two presumed parent populations the average measurements of the one derived from them are intermediate in value. As far as can be ascertained from the best evidence available, the cross results in a nearly perfect blending of average values, determined by the proportions in which the parent populations have mixed. This observed situation cannot be reconciled with views expressed by some geneticists. The fact that the cross results in a blending of average measurements makes possible a classification of the races of man based on these criteria. The variabilities of the crossed series are seen, in general, to be no greater than those of the parent populations. The available material is hardly adequate to give any exact indication of the forms of the distributions of metrical characters in the populations sampled, but there is no suggestion that any of these depart appreciably from normality.

Miss M. L. Tilidesley.—Comparison of the face and jaws of a mediaeval (Scarborough) and a post-mediaeval (London) population (4.10).

Visit to Nottingham Caves.

Friday, September 3.

Presidential Address by Prof. J. H. Hutton, C.I.E., on Assam origins in relation to Oceania (10.0).

Mr. H. A. Fosbrooke.—A new Bantu tribe (11.0).

The Sonjo are a small tribe of about 2,500 souls, isolated in the middle of Masailand, and situated in country about 15 miles west of Lake Natron in Tanganyika territory. They are new only to scientific literature and discussion, having been under administration since German times.

The object of the series of slides is to show that there still exists at least one Bantu tribe in a practically untouched state, in that the Masai have presented a barrier to all those influences—slave raiding, trade, missionary activity, both Christian and Islamic, tribal admixture, etc., which have so fundamentally altered the structure of the majority of Bantu tribes.
They are thus deserving of attention in that they provide a 'norm' on which a study of the changed and changing Bantu can be based.

Mrs. Nora K. Chadwick.—A study of poetic inspiration and the trance of the seer (11.35).

The materials for such a study are wider than is generally supposed. Oral literature is one of our most important sources of information for the phenomenon of trance, and is indispensable to the researches of psychologists into the mental condition of the seer. The ancient literatures of northern and western Europe afford valuable evidence especially for the more technical side of manticism. From Asia and Polynesia much additional information is to be obtained from stories of the past and from current oral poetry. In Africa certain traditional institutions have an important bearing on contemporary mantic practices. A comparative survey leads to the conclusion that prophecy is generally uttered in the most elevated form of speech of which the seer is capable—most commonly in poetry as we understand the term; but poetry does not differ essentially from chanted prose. Poetic inspiration is not distinguished from prophetic inspiration among backward and primitive peoples. Wherever manticism is a living institution inspiration has reference primarily not to the form, but to the matter, and embraces the whole field of human knowledge—of the present and the past, as well as the future. Recent observers are tending to stress the intellectual element in the seer's equipment.

Dr. Christoph von Fürer-Haimendorf.—Field-work among the Konyak Nagas of Assam (12.15).

The Konyak Nagas, among whom I have done field-work for twelve months in 1936 and 1937, form the north-eastern group of the Naga tribes of Assam and live in the mountains between the Patkoi Range and the Brahmaputra valley. Only a small part of the Konyak country is under British rule; most villages enjoy complete independence and many of them have even never been visited by any white man.

In their appearance and in many aspects of their culture the Konyaks are considerably different from the other Naga tribes. There is no doubt that they largely represent an old type of culture, which was at one time prevalent all over the Naga country.

Their form of agriculture is very primitive: taro, not rice, is in many villages the staple crop and cultivation on irrigated terraces is completely unknown. Cattle-breeding is not done to a great extent, and the fact that the pig is to this day the sacrificial animal proper to most ceremonial occasions suggests that, except for dog and chicken, it was until recently the only domestic animal.

The Konyaks are the only Nagas who blacken their teeth; one group of them has elaborate face-tattoos and the men very often go completely naked, while the women wear only minute skirts.

The most outstanding feature in the social sphere are the autocratic chiefs, who form a nobility with enormous privileges. The chief's clan is not exogamous like the clans of the commoners, but endogamous; for only a man of pure aristocratic blood can succeed as chief.

The religion of the Konyak is characterised by the cult of a sky-god and the almost complete absence of any spirit-worship. Like all Nagas the Konyaks are inveterate head-hunters.
Afternoon.

Discussion on Anthropology and administration.

Mr. Kingsley Roth.

Mr. G. E. Harvey.

A century of British rule has nearly quadrupled the population of Burma and greatly raised the standard of living, but it has destroyed some of the healthiest elements in the pre-British social organism, and the increase in crime which has been taking place for generations is symptomatic. Whereas in England since 1870 murder has fallen by nearly half, in Burma it has risen from 26 to 62 murders annually per million people. Murder is thus eighteen times commoner than in England, and this, the all-Burma figure, would be even higher but for the inclusion of backward tracts indirectly administered through the pre-British hereditary institutions. There are 'progressive' districts under direct administration where the murder rate is equivalent to three murders a day all the year round for the population of Greater London. The causes are spiritual rather than economic. At the Annexation of Upper Burma in 1885 the Burmese Buddhist Church voluntarily preached submission to British rule, yet we refused its request for the continuance of its penal jurisdiction over its own clergy, with the result that holy orders are now habitually used as a cloak by charlatans and even by criminals. Our refusal was characteristic of 'administrative efficiency' which fails to get under the skin, nor will anthropological training (which our officers sadly lack) help unless they are left long enough in a district to know the people—the usual term is three or four years at most, yet one does not even begin to know a district till the fifth year, for if friendship takes time among ourselves it takes infinitely longer with men of an utterly different language, skin colour and tradition, nor will they confide in those whom they know to be only birds of passage. Hence the gulf between the rulers and the ruled evidenced by the fact that the bloody outbreaks of a few years ago came as a complete surprise to the Burma Government.

Mr. H. A. Fosbrooke.

Saturday, September 4.

Excursion to Sherwood Forest and Laxton.

Sunday, September 5.

Visits to Gresswell Caves and to Leicester Forum excavations.

Monday, September 6.

Discussion on Presidential Address (10.0).

Dr. A. C. Haddon.—Introduction.

In a discussion of distributions in Oceania it must be borne in mind that there have been a considerable number of ethnic and cultural migrations
from Indonesia into Oceania, the majority of which spread eastward, skirting, or in some instances settling upon, the north coast of New Guinea. Some of these migrants remained in Melanesia, including the Masim district of New Guinea, while others extended into various parts of Polynesia; the Fiji islands show a mixture of Melanesian and Polynesian cultures. A northern migration from Indonesia passed through Micronesia to Hawaii. The culture of south-eastern Polynesia belongs essentially to the southern spread, but was for a time influenced by the northern Hawaiian culture. There was also a late spread of culture from Micronesia into parts of Melanesia, one feature of which was the loom.

These spreads of culture took place at various times and doubtless each was characterised by special features. These have not as yet been accurately determined, although Graebner, Rivers and others have made noteworthy attempts and have suggested a relative chronology.

We may assume that kava-drinking was earlier in Oceania than betel-chewing, and I think that the coiled method of making pottery was older than the modelled technique. As all these spreads must have been made by seafarers, it occurred to me, over thirty years ago, that a study of the canoes of Oceania and New Guinea might afford some useful clues. Some years ago I induced Hornell to undertake an investigation of the canoes of Micronesia and Polynesia and I interested myself in those of New Guinea and Melanesia. Hornell’s researches have already been published and mine and our joint work are in the proof stage. Owing to the disappearance of many types of craft and the modification of others no clear-cut story can be told, but we have been able to indicate the distribution of various types and to suggest a relative chronology.

Sociological spreads are more difficult to trace than those of material culture. Rivers was the first to tackle this problem on scientific lines and his main generalisations, which were based upon certain associations of customs and material objects, must form the basis for future discussion. As an example of method, a short paper by Deacon shows that the cult of the Kakikan society of Ceram (a cult that doubtless had a wider extension in Indonesia) spread along the north coast of New Guinea into Melanesia. In New Guinea certain elements of the cult were stressed, while others were emphasised in Melanesia.

We may safely assume that the great bulk of the social and material culture of Oceania came directly from Indonesia.

A critical study of cultures in Indonesia has yet to be made, though it is evident that numerous spreads of culture have taken place from south-eastern Asia and from India, and doubtless there have been various centres of local evolution in Indonesia.

Students have long recognised the striking similarity between the cultures of Assam and those of Indonesia and Prof. Hutton has just demonstrated to us remarkable cultural similarities between Assam, Fiji, the Marquesas, and Madagascar. The last three marginal areas point to a common cultural home in Indonesia.

The immediate question is the relation between Assam and Indonesia. Which received a definite cultural complex from the other? Our President has given us a valuable insight into the culture of the Naga hills of which the Konyak is the oldest and in some respects the richest. He has also given us a highly suggestive account of the relation between the slit gong and the canoe and with other important associated cultural traits. I consider we may accept his suggestion that a rich cultural complex spread from Indonesia into Assam for some unknown reason and at a date that is not yet established.
It is evident that the Indo-Oceanic problems are very complex. It is first necessary to identify the original cultures, a task which is very difficult on account of the assimilations and consequent changes that have taken place. We must discover the relative chronology of these spreads, with the hope that ultimately we can arrive at a dateable chronology. Our President's address will assist towards the elucidation of these problems.

LADY RAGLAN.—_The green man in church architecture (10.35)._ 

In many English churches, dating from the twelfth to the fifteenth centuries, are to be found carvings of men's faces with oak or other leaves issuing from the mouth, nostrils, etc. It has usually been supposed that these carvings were allegorical or merely fanciful, but the wideness of their distribution in Western Europe, their general similarity, and the important position in churches which they so often occupy, suggest that they had some more concrete significance. 

Slides are shown illustrating the various types which the figure assumes, and a connection is suggested with the personage known as the 'Green Man,' the 'King of May,' or Robin Hood, who was the chief actor in the May-day festivities, the form in which the most important of pagan rites survived into Christian times.

Prof. S. H. Hooke.—_Cain and Abel (11.15)._ 

A short discussion of the origin and meaning of the fratricide motive in early myth and ritual, and its later development in legend and folklore. Osiris and Set in Egyptian myth; Mot and Alein in the Ras Shamra texts; Cain and Abel in Hebrew myth. Racial, political and ritual elements in the myths. Conflict between pastoral and agricultural modes of life. Significance of the motive in Western folklore.

Mr. C. F. Tebbutt.—_Cart-front designs (12.0)._ 

In the counties of Lincoln, Leicester, Rutland, Huntingdon and Cambridge, and in parts of Nottingham, Northampton, Bedford, Hertford, Essex, Suffolk and Norfolk, farm carts and wagons sometimes have their fronts ornamented with a design known to wheelwrights as 'the spectacles.'

In the typical example the front is double boarded and the design is cut out of the front boarding to expose that at the back. At the extreme edges of the above area degenerate and freak forms occur, but all obviously derived from the same source.

Inquiries among wheelwrights have failed to find a purpose or origin of the ornament, but it must originally have had a good luck, or fertility, significance.

The Fenland and its borders would appear to have been the distributing centre of the design, for there most examples still occur, and nearly all are typical ones.

The ornament occurs most frequently on the scotch cart and less often on tumbril carts and wagons, and is not entirely confined to agricultural carts.

The field of research among English farm implements is a promising one and is almost untouched. In a very few years it will be closed for ever.
Mr. R. U. Sayce.—Rope-twisters (12.30).

In the nineteenth century a simple hook appears to have been used nearly everywhere in the British Isles for twisting straw or grass into rough ropes or bonds, which were used for thatching roofs and ricks, for tying bales of hay, etc. The fate of this hook is typical of many other simple rural implements. In many districts it has gone out of use; in some it has been entirely forgotten.

It is still possible to collect these hooks in some districts, and the patterns show a great variety of them. The older examples seem to have been made of wood—a bent ash or hazel stick, or a small branch whittled into the proper shape. At one end they have a handle rotating by means of a swivel which is often simply but ingeniously contrived. The later types consist of an iron rod, about three-eighths of an inch thick, bent more or less into the shape of a brace and bit, and provided generally with two rotating wooden handles through which the iron rod passes.

Observations by many people are needed to record all the types of this implement and its distribution. If we are to explain these things, we must first collect all the facts. It would be interesting to work out the history of the different patterns and to see how each had arisen and spread from its immediate homeland. Work of this kind would involve an intimate knowledge of the farm worker and the rural craftsman, and of the economic and social conditions of the countryside.

The name of this hook also shows some interesting local variations. From Yorkshire down to Devon and Cornwall it has various forms such as *wem, wim, wumble, whinble, wimmerill*. In Cumberland the hook is called a *symetturner* (cf. O.N. *sima*, a rope or bond), and in Scotland and the Shetlands there are several variants such as *simmet, simmun(d)*, etc. In Donegal, Anglesey, Banffshire, etc., the name appears to be *trahook, throwhook, thraahook* (cf. German, *drehen*), while in the Gaelic districts we find *sugain* or *shugain*, with anglicised variants like *soogaun, suggawn*, or *suggane*.

**Afternoon.**

**Joint Discussion with Section E (q.v.) on Natural and cultural regions (2.0).**

**Tuesday, September 7.**

Mr. J. E. Sainty.—Preliminary report on a long mound at West Runton, Norfolk (10.0).

Prof. John Murphy.—The psychological origins of magic (10.35).

All magical actions are more or less simple or complex gestures. Conscious gestures are pictorial, and as such are complete in themselves, like a drawing in childish or undeveloped art (which itself originates in gesture). Many unconscious gestures are actions at the stage of conation or wish, and never pass beyond it. Examples, in which the parallel to magic is evident. On the other hand, in the magical art of the Magdalenian caves there are characteristics of unconscious gesture such as 'action at a distance,' power ignoring space and time, and irrational identification or solidarity between the persons concerned.

This we relate to the Freudian wish as the origin of gesture, in which (e.g. in the inclination of the player's body in the desired direction of the
ball, or in salivation where the act of digestion is ‘touched-off’ but may never be actual or completed) there is the motor ‘set’ of the bodily mechanism towards the fulfilment of the wish. The connection of this with the art of the caves as magic is to be noted, as well as with the origin of primitive art, since a resemblance on the wall of the cave to the desired food-animal sets in motion the mechanism of wish, gesture and magical purpose, which creates the likeness as a whole.

Miss Eleanor Hardy.—Pollen analysis and archaeology (11.15).

The sequence of vegetation since the last Ice Age can be traced from analyses of the pollen grains preserved in recent deposits. This gives an indication of the climate and environment with which early man had to contend at different periods, and which to some extent controlled his mode of life.

Examination of the stratigraphy of peat bogs has revealed several distinct climatic phases. These phases and the history of the vegetation can be correlated with archaeological periods, and used as an arbitrary time-scale for dating finds of unknown age.

In places where there have been changes in the relative levels of land and sea, information as to the date and significance of these movements is yielded by investigation of submerged forests or of bogs on the uplifted land.

In England, work on these lines has not been so fully developed as it has in Sweden, its country of origin. In many parts of this country bogs must have been destroyed by drainage and cultivation, and comparatively few remain untouched. It has, however, been possible to use pollen-analysis for archaeological purposes in several instances.

Dr. A. N. Tucker.—The background of Central African folk tales (11.50).

Three aspects are discussed:
1. The principal themes underlying the stories.
2. The historical or sociological background revealed by the stories themselves.
3. The setting in which the stories are told and the manner of their telling.

1. Reference to Dr. Alice Werner’s Myths and Legends of the Bantu. Although the Bantu live to the south of the people here discussed, the topics which form the basis of legend are characteristic for all Negro races—including even the American Negroes.

(a) Stories of the beginning of things: Man’s origin, the origin of Death and Life, local versions of the Fall, and of the Flood.
(b) Stories of the supernatural: Gods and Ghosts, the Cult of the Dead, tribal Heroes who have attained the status of demi-gods, Werewolves, Half-men and other monstrosities.
(c) Unexplained phenomena of nature: Rainbow, Lightning.
(d) Animal stories: Stories of the type Lion versus Hare, stories of animals and people, the Language question.

2. Obvious historical and sociological data supplied by stories. Examples of the less obvious (from the Bari).

(a) The ’dupi myth and the light it throws on pre-history.
(b) Light thrown by animal stories on clan organisation in the past.
3. The setting of the stories in relation to the occasion, the narrator, the audience, their reaction, the musical element.
Mr. W. Fogg.—*A tribal market in the Spanish zone of Morocco* (12.25).

*Söq l-Tnin d Sidi l-Yemání,* a traditionally established Monday market held near the *shyïd* (shrine) of Sidi l-Yemání, is one of the five largest of the tribal markets, of which there are more than one hundred, in the Spanish zone of Morocco. It is one of the two principal country markets of the ‘Arab’ tribal districts (Garbiya, Hlot, Bdâwr, Mzóra, Bdâwa) in the Western plains of the Spanish zone, but is frequented also by Jbâla tribesmen (Bni Msauvar, Jbel Hbib, Bni Arós, Bni Gérfat, Ahl Srif) from the neighbouring mountains to the East. It is located at some fifteen miles to the North East, approximately, of Laraîche.

As far as the short allotted time allows, the paper gives details of (a) the market organisation for public security and legal transactions, (b) the market officials and their functions, (c) the plan of the market by trader and artisan groups (*mwâda*), (d) characteristics of some of the *mwâda*, (e) some aspects of the social function and sociological significance of the market, (f) a summary of the changes effected by the Spaniards.

M. André Varagnac and M. Georges Rivière.—*Folklore in France* (12.40).

The study of folklore is developing so steadily in most European countries that we constantly find ourselves faced with new problems.

It is no longer advisable to rely merely on personal initiative; the work of the individual investigator needs guidance and organisation. Until a comprehensive plan has been agreed upon, many facts will be overlooked and the comparative method may even be rendered useless.

Therefore it appears necessary to organise our work on a basis of international co-operation. With the view of securing the kind assistance of our colleagues in each country we would suggest the establishment of an International Committee of Folklore Methodology.

This Committee would decide:

- on a standard classification of folklore facts;
- on a standard index for folklore bibliography;
- on a series of facts to be noted on every national folklore atlas;
- on a code for the elaboration of folklore maps.

If all countries interested at present in folklore research would co-operate in the above tasks, it would be possible, in the near future, for all folklorists to apply the comparative method in the whole field of European facts.

**Afternoon.**

Dr. Margaret Murray.—*Excavations at Petra* (2.15).

The *Blütezeit* of Petra was under the Nabateans, just before and just after the Christian era. Before that period the Petra valley was merely a place of refuge, and not continuously inhabited. Under the Nabateans Petra was the chief meeting place for the caravans trading to the West from Arabia and India. The Nabatean inhabitants lived in caves, in front of which were structures—chambers and courtyards—built of stones. Excavations in caves produced great quantities of fine pottery, both plain and painted. The same kind of pottery in the same large quantity was found in the town dump, which was many feet thick, but the pottery showed no change in form or in painted designs between the pieces found at the top and those at the bottom of the dump.
Mrs. E. M. Clifford.—*Types of long barrows on the Cotswolds (2.50).

The Cotswold hills form part of the so-called prehistoric highway of England and the area is justly famous for its long barrows, which are built of local materials. Three types of chambered barrows are distinguished and these include three of the four known examples of double cruciform type (Uley Bury, Nympsfield and Notgrove), the last named differing from the others in having an ante-chamber approached from a horned entrance with two walls and a central dome-like structure in which there was a cist containing human bones. The barrows are formed of orthostats and dry stone-walling and are surrounded by revetment walls, which are often supported by extra-revetment material. This in its turn forms the outer edge of the covering of the mound, which is largely of stone. They are found on high ground and their connection with trackways is probable. It is possible they were used over a long period for the burial of the ruling classes. The type of skull is dolichocephalic except in three cases, one of these being the Bisley trephined skull, and beaker ware has been found in four long barrows. Neolithic A ware (including pottery spoons), Neolithic B beads, and bone tools are among the objects found, and the animals include horse, roe-deer, red deer, ox, sheep or goat, and dog.

Miss C. A. Simpson.—*Trackways (3.10).

Mr. H. J. E. Peake.—*Some problems of the Neolithic (3.30).

Prof. V. Gordon Childe and Mr. W. Thorneycroft.—*The experimental production of phenomena distinctive of vitrified forts (4.10).

A model *murus gallicus* was built 12 ft. long × 6 ft. wide × 6 ft. high using bricks for the faces. A raft of close-set pit props formed the foundations for the core and one face, and the faces were tied together above by 4 tiers of transverse beams set at vertical and horizontal intervals of 16 ins. Each layer supported other timbers, and the rest of the core was filled with basalt rubble. The whole was ignited from timbers heaped against both faces in a strong breeze. The wall burned for 6 hours and after cooling the three lowest layers of rubble were found fused into a solid mass. In this mass the casts of timbers and other phenomena, observed in the vitrified ramparts of prehistoric forts in Gaul and Scotland, were faithfully reproduced. In building the wall 1 ton 6 cwt. dry timber and 7 tons 7 cwt. of basalt had been employed and over 14·5 cwt. vitrified basalt was obtained. The experiment was repeated on a smaller scale using schist actually employed in the prehistoric rampart of Rahoy and yielded confirmatory evidence. Thus is confirmed the most authoritative account of vitrification that attributes it to the combustion of a stone and timber rampart such as the *murus gallicus* of Cæsar.
SECTION 1.—PHYSIOLOGY.

Thursday, September 2.

Presidential Address by Dr. E. P. Poulton on Heat production, nutrition and growth in man—some new views (10.0).

Contributions of physiology to the health of the individual and the community (11.15).

Prof. D. Burns.—Introduction.

Human progress is marked by a series of triumphs of man over so-called 'natural forces,' so that he leads an 'unnatural' life, eats food more sophisticated than ever before, and is protected against those rigours of 'Nature' which otherwise would weed out the unfit. This raises various problems some of which have to do with the adaptation of the individual to his environment. The mal-adapted individual cannot stand the strain of modern life. Other problems are associated with the relation of the individual to the community. The preservation of the less fit with no restraint on their breeding causes the community to carry an increasing load at the bottom of the biological scale, while the slowing down of the birth-rate, a universal concomitant of higher civilised communities, affects the fitter classes.

If civilisation, as we know it, is to survive, some logical plan of living must be evolved. No plan can be evolved unless we know just exactly what we mean by a healthy life and a healthy community. As physiology is that branch of science which deals with the functions of the healthy individual and is especially interested in the mechanism of adaptation of organism to environment, it ought to contribute authoritative information on these vital problems.

Dr. A. L. Bacharach.—Some applications of animal dietary experiments to problems of human nutrition (11.45).

Mrs. C. M. Burns.—The physiological cost of reproduction (12.15).

In view of the interest taken in the campaign for a fitter nation, it is advisable to know what is the most suitable (a) age for initial reproduction; (b) rate, and (c) extent of reproduction, in relation to the health of mother and child. For this purpose the health records of 16,500 children over the first five years of their lives, and of 30,000 women under the care of the Maternity and Child Welfare Scheme over a similar period were studied by the courtesy of the Medical Officer of Health for the County of Durham. The women came into the investigation at the birth of a child. Many had other children during the period of study, i.e. they represented the actively reproducing section of the community. At least 98 per cent. belonged to the classes normally covered by State insurance, or were living under the social conditions characteristic thereof. Under relatively homogeneous social conditions great variations occurred in the chance of life in different biological groups. The age of the mother, the position of the child in the
family and the rate of reproduction are all important factors in determining infant and child death-rates, and death-rates both from maternal and all causes in mothers. In the early stages of the decline in the birth-rate, most of the decrease took place in biological groups with very high death-rates, and a decline in infant death-rate accompanied the fall in the birth-rate. Latterly, much of the decline has occurred in groups with low death-rates, so that the total infant death-rate may become stationary or even rise. The decline, however, has mainly tended to cause the groups with high still-birth and high maternal mortality rates to become a larger proportion of the total. The apparent stability of these rates therefore probably hides a real decrease in the individual groups. Although among all the women of the age under consideration in the area, deaths from maternal causes constituted only about 10 per cent. of all deaths, while among the 30,000 they formed about 50 per cent. of the total deaths, yet the total death-rate among the reproducing women at each age did not exceed that among all women of the same age, i.e. reproduction probably weeds out the unfit rather than adds to the total death-rate. A high maternal death-rate will therefore be found under bad social conditions where the unfit abound, and also under good social conditions where other weeding-out processes are few. Within the individual groups, the influence of overcrowding as measured by rooms per person appeared unimportant. (The influence of congested areas as distinct from overcrowded houses could not be measured.) Despite ten years' acute industrial depression the total death-rates among women and children of the ages studied had fallen by 20 per cent. during that period.

Afternoon.

Dr. G. E. Friend.—*Indices of health* (2.15).

Prof. Dr. E. Atzler.—*Die Bedeutung der Ernährung für die Leistungssteigerung* (2.45).

Prof. S. J. Cowell.—*The aims and methods of nutritional science* (3.15).

The science of Nutrition, as commonly defined to-day, covers such a large part of the field of biological science that it is not surprising that its study is being pursued by those with very varied training in very diverse surround-
ings. Physicians, physiologists, biochemists and pure chemists have con-
tributed to the recognition and identification of essential food constituents; physiologists and biochemists have probed more and more deeply into the problems of food requirements and intermediary metabolism; physicians at the bedside and field workers among the populations of the world have been searching for the signs of faulty nutrition and have been trying to explain and correct them. All these activities have been linked together, the work of one group inspiring that of another; all have made possible the rapid advance of the knowledge of nutrition. The practical interest dis-played in the application of the recently acquired knowledge to human welfare by those who have contributed most to the discovery of its 'fundamental' principles, has been a striking feature of the development of Nutrition as a special aspect of scientific study.

General Discussion on *Physiology and health* (3.45).
Friday, September 3.

Dr. F. W. Edridge-Green, C.B.E.—The fundamental facts of colour vision and colour blindness (11.0).

If a large number of persons be examined with a spectroscope the number of colours seen by each varies considerably. Some see seven colours in the spectrum, others six, five, four, three, two or none, and therefore may be correctly classified as heptachromic, hexachromic, pentachromic, tetrachromic, trichromic, dichromic or achromic. The length of the visible spectrum varies considerably and is an independent defect.

The spectrum may also be examined in another way with or without a double-image prism; it may be divided into a series of monochromatic divisions and these may be projected with the aid of a double-image prism upon a screen, the red side of one image may be made to touch the violet side of the other and yet no one in a large audience may be able to see any difference between the two; the monochromatic division is therefore a physiological unit.

The older theories of colour-vision do not agree with the facts. For instance, a mixed white compounded of red, green and violet lights which is made to match a simple white behaves differently, when viewed after fatigue with red light, from the simple white. Again 90 per cent. of the colour-blind agree with the normal white equation but may also agree with anomalous equations.

Dr. A. C. Frazer and Dr. H. C. Stewart.—Detoxication of bacterial toxins by adsorption at the oil-water interface in finely dispersed oil-in-water emulsions (11.30).

Mixture with finely dispersed oil-in-water emulsion prior to injection renders a lethal dose of bacterial toxin quite innocuous. This can be shown with such toxins as diphtheria, tetanus, staphylococcal, and Welchii toxins, to mention a few, and a similar detoxication has also been demonstrated with Cobra Venom. The detoxicating mechanism is essentially that of adsorption of the toxin at the oil-water interface, which prevents the toxin from exerting any harmful influence upon the body cells. Adsorption at the interface does not, however, interfere with the antigenic properties of the toxin, which are essential for the elaboration of protective antibodies. The adsorption is more rapid and complete at body temperature than at room temperature.

The administration of finely dispersed oil-in-water emulsion in toxæmic conditions modifies the course of the disease to a marked degree, possibly due to a similar adsorptive action. In the administration of vaccines and similar preparations the toxic reaction obtained with large doses can be avoided by admixture with emulsion prior to injection.

Mr. S. J. Hopkins, Mr. G. A. jelly, Mr. G. C. Kennedy and Mr. A. J. Walker.—The effect of small meals on the metabolism of muscular exercise (12.0).

Prof. Dr. E. Atzler.—Einige Beobachtungen über die ermutungsbekämpfende Wirkung von Colopraparaten (12.30).

Afternoon,

Visit to Boots’ Pharmacological Laboratories, Island Street, Nottingham.
Monday, September 6.

Joint Discussion with Sections A (q.v.) and I on Surface action in biology (10.0).

Tuesday, September 7.

Physiology as a subject of general education (10.0). (For full report of this discussion see p. 474.)

Prof. Winifred Cullis, C.B.E.—Knowledge of the body's working the basis of healthy living.

Dr. H. Magee.—The importance of physiology education from the cultural and the utilitarian aspects (10.30).

The subject of this discussion involves consideration of the purpose of education in general, as well as of the case for physiology as a subject of general education. The aims of education are the development of the intellect and the training of the individual for the material affairs of life. The study of physiology, like other branches of learning, promotes the orderly development of the human mind and goes to satisfy man's inherent desire for knowledge of any kind. The practical end is, however, the most important argument for teaching physiology: 'as the master-key of medicine its practical value is self-evident,' but knowledge of physiology would be of great value to the general public.

Mothercraft is the most important occupation of womankind, for there is much truth in the saying 'The hand that rocks the cradle rules the world.' The child is completely dependent on its parents, and especially on its mother, for its every need, and whether it is to grow up to healthy adult life depends in great measure on the care and knowledge the mother brings to bear on her task. The problems concerned with the nurture of the child belong mainly to applied physiology, and it is, therefore, highly desirable that parents, and especially mothers, should possess some knowledge of the subject. The importance for the health of the present and coming generations of the establishment of habits of healthy living needs no proof; in laying down the foundation of these, the influence of teachers as well as of parents is dominant. There is abundant evidence that the education authorities in this country are fully alive to the desirability of instructing school children in physiology and hygiene. If the population were better informed in these subjects than at present, the elimination of many of the prevailing absurd practices, for example in regard to solar radiation and slimming, might be anticipated with some confidence. The present enthusiasm for physical culture and games is highly commendable, but it must be remembered that the mind and its faculties are of a superior order to the physical body and that character and grit are mental rather than bodily attributes.

Prof. R. C. Garry.—Human physiology in the teaching of biology (11.0).

It is a sound pedagogic principle to proceed from the known to the unknown.

In the teaching of Biology, however, the known, or at least the familiar, human body is largely ignored.
In schools, and even in universities, outside the medical curriculum, biological teaching concentrates largely on the lower forms of life. Not infrequently, such forms are difficult to obtain, are subject to seasonal effects and require relatively expensive apparatus for their study. Moreover, such study too often lacks direct applicability to the affairs of everyday life, and, very important, lacks the emotional appeal which is so necessary to make a subject attractive in school and later.

On the other hand, study of the human body can inculcate most of the biological first principles and has direct bearing on many of the most urgent problems which face mankind. With the human body as experimental material, elementary classes in biology can be conducted with the minimum of apparatus.

Dr. L. P. Lockhart.—Physiology as a part of general education (11.30).

The approach to the subject is by way of clinical medicine practised within industry. The thesis that a grasp of physiological principles is essential to an objective understanding of reality was developed by Herbert Spencer, but modern trends in industrial communities give added weight to it. The large aggregations of people working in close co-operation in an intricate system can only remain healthy and efficient if their legitimate needs are met in full measure. Systems of industrial welfare, national physical education, nutrition and housing cannot be viewed in isolation but form part of a unity. Those who administer national and industrial affairs need not be technical physiologists, but they need to be so educated that they can grasp the essentials of the technical evidence submitted to them and be aware of its relevance and importance. Much of the neurosis which damages large communities and renders individuals inefficient, substandard in health or asocial in behaviour arises from the physiologically unbalanced lives they are forced to lead. Ignorance of physiological needs operates not only on the personal life but on the lives of those controlled or influenced by persons who lack awareness and understanding of what is physiologically desirable. It is not suggested that the mere addition of a subject to the school curriculum will effect a change. What is far more necessary is that the general basis of educational subjects should be interpreted to pupils in terms of natural laws, and it is obvious that this must apply mainly to secondary schools. There is a physiological basis to social change and evolution which is historically of far greater moment than the doings of rulers and statesmen, and it would be well if those who dictate examination policy would realise this more fully than they appear to do. The plea put forward is that unless physiological principles are inculcated as a part of general education there is no proper foundation for the development of sound health, sane morals, nor for the later understanding of those psychological conceptions which in the end determine the manner and objective of social and individual development.

General Discussion on Physiology as a subject of general education (12.0).

Afternoon.

Demonstration by Dr. L. F. Richardson, F.R.S., of An electrical model of reciprocal inhibition (2.30).

Two osclim lamps in series with resistances are connected in parallel to a battery through another resistance. When the resistances and voltage have
been suitably adjusted, either lamp will glow; but both lamps will not glow simultaneously, although they are both in permanent connection with the same battery. An external disturbance can be used to start a glow in the extinct lamp, and the glowing lamp is then automatically extinguished. The experiment was first described in the *Psychological Review* (U.S.A.), 1930, 37, 214–227. An investigation of the cause of the phenomena is in progress.

**SECTION J.—PSYCHOLOGY.**

Thursday, September 2.

Dr. R. B. Cattell.—*The psychometric versus the intuitive approach in the study of personality* (10.0).

A controversy over the use of the Binet test in psychological clinics has brought to a head a difference of viewpoint, which has become more evident in recent years, between those who believe that personality is ultimately describable in terms of mental measurements and those who believe it is only to be intuited as a whole. The cleavage runs from applied psychology, where it takes the form of an opposition between mental assessment as an art and as a science, to theoretical psychology, where it becomes in the main an irreconcilability between *gestalt* and *geisteswissenschaftlich* psychology on the one hand and factor psychology on the other.

The practical and theoretical implications of the two viewpoints are examined in detail. It is contended that in practice the psychometric approach already gives more reliable results and that in theory the intuitive approach is nothing less than a disguised attempt to escape from the rigours of scientific method. The energetic prosecution of clinical research has been impaired by deflection of effort towards the specious attractions of intuitive methods, but intuition, because it involves projection of the therapist's own personality, is in the end nothing more than a source of error, though in the beginning it may provide a useful scaffolding for a structure of objective research.

Prof. T. V. Moore.—*The synthetic sense and intelligence* (10.45).

I. *The contribution of pathology to mental analysis.*

Pathology gives us a very valuable rule for the differentiation of functions. Whenever a single function is destroyed after a certain type of pathological change:

(a) The function destroyed is in some way connected with the normal activity of the tissue that has undergone pathological change.

(b) The function destroyed must be recognised as distinct from the functions that remain intact.

II. *Pathology of perception.*

After certain pathological changes in the brain the patient

(a) is still capable of receiving certain sensory qualities;

(b) is incapable of interpreting the sensory qualities so received,

(c) but may still possess intact the power of interpretation.

(Cases illustrating these conditions are given.)
If these facts are so, then, in virtue of the rule of pathology we may say that:

(a) The function destroyed is in some way connected with the normal activity of the cerebrum.
(b) The function destroyed is not the power to receive sensations, nor the power to interpret the data of sense.

There remains, therefore, a mental function intermediate between the power to become aware of sensory qualities and the power to interpret the data of sense. This intermediate function is here termed the *synthetic sense*.

III. *The Theory of Perceptions.*

The synthetic sense is a complex group of functions. Thus the ability to synthesise tactual data may be destroyed while the power to synthesise other sensory data may remain intact.

The process of synthesis is to a large extent dependent on past experience, but experimental data show that the revival of the images of past experience is not an essential element of the synthesis.

But what *Gestalt* psychology recognises as differentiation between figure and background is one of the elements in the process of synthesis. This differentiation is not interpretation, but a necessary condition that interpretation may take place.

Sensory data of size, distance, relative position of object and parts, motion (made possible by past experience) are combined with the present sensory qualities into a single phantasm of perception. This synthetic product (not the naked sensory qualities) is the basis of perception.

The old sensationalism attempted to explain perception on the basis of sensory qualities.

The Berlin school of configurational psychology transcended sensationalism by pointing out the interplay of figure and ground and the sensory basis of relational perception, rejecting the very important contribution of the Gratz school which insisted on the *Gegenstände höherer Ordnung*, the intellectual elements in perception.

Pathology differentiates for us very clearly:

(a) The awareness of sensory qualities.
(b) The sensory synthesis.
(c) The interpretation of sensory data.

Prof. C. Spearman, F.R.S.—*The Chicago experiments* (11.30).

Dr. R. H. Thouless.—*The effect of distance on apparent velocity* (12.15).

It is a fact well known to experimental psychologists that apparent size and shape are not determined only by the size and shape of the retinal image of a seen object but to a considerable degree (varying with different individuals) also by the real size and shape of the object itself. Thus the apparent sizes and shapes of objects can be regarded as intermediate between retinal and 'real' sizes and shapes. The same principle holds for apparent velocity. Two objects moving with equal real velocities across the field of vision at different distances from the eye have different apparent speeds, the near one appearing the faster. If, however, they are moving so as to give equal retinal speeds, the far one appears to be moving the faster. Apparent velocity also is a compromise between retinal velocity and real velocity.
The degree of 'phenomenal regression' to real velocity differs in different individuals and these differences prove to be persistent and characteristic of the individual concerned. It is not known whether these differences are of any practical importance. They do not appear to be correlated with other visual phenomenal regression effects.

**AFTERNOON.**

Mr. H. G. Maule.—*Movement study in industry (2.0).*

In the course of an investigation of time and motion study in the laundry industry several facts have been disclosed, most of which are simply in agreement with the work of previous investigators.

Output graphs under different circumstances of work have been compared. Instances of long periods of uninterrupted work show the usual fluctuation in hourly output. A considerable falling off of output is noted towards the end of a long day's work. Where morning rest-pauses are given the morning output is found to be more consistent. In one instance where rest-pauses were given in the morning and in the afternoon the greatest consistency of output was recorded. Though this is in agreement with the work of other investigators, it is contrary to the common opinion of most of the workers themselves.

A combination of time study and motion study demonstrated that, in the instance where production was highest and hourly variation least, the actual movements of the workers in the performance of their task was the best. These workers had been given definite training at an early stage. It is far more common to find that workers 'pick up' the methods as best they can.

By means of ciné pictures of these workers improved methods of work have been shown to a large number of workers.

In one instance prolonged training was given to a team of girls. The effects of this were: *(a)* improved production; *(b)* improved quality; *(c)* definite satisfaction on the part of the workers.

In conclusion, it may be claimed that the work has demonstrated the possibilities of using a combination of time studies and motion pictures for the training of future operatives in repetitive jobs.

Mr. J. H. Mitchell.—*An experiment in the selection of sales managers (2.45).*

A national sales organisation had a problem concerning the selection from the sales force of managers to take charge of branches in various parts of the country. The work of these managers is to control a group of 60 to 100 salesmen engaged in door-to-door selling of vacuum cleaners.

After a study of successful and unsuccessful managers, a method of selection was involved, based on:

*(a)* History before joining company and during period as salesman.

*(b)* Impressions on a rated interview.

*(c)* Results of mental and temperamental tests.

Hitherto the most successful salesmen had been appointed where possible to managerial positions. It was found that there was no correlation between selling ability and managerial ability.
Mrs. W. Raphael.—Factors in the likes and dislikes for work (3.30).

This investigation is based on information given during interviews with about 1,000 employees—clerks, shop assistants, waiters and factory workers. They spoke with complete freedom as all the interviews were anonymous.

The social environment of the work was generally found to be of more importance in determining the happiness or unhappiness of the worker than the job itself. Perhaps the most influential single factor making for like or dislike of work was the first rank supervision. Great feeling was also aroused by real or imaginary unfairness. For example, wages were much more often mentioned as a cause of grievance in a section where pay was good but where it was slightly better in a neighbouring section, than in a section where pay was low but equally low throughout the firm.

The paper is chiefly concerned with examples of factors which determine dislike of work and of the beneficial results of altering some of these factors.

Dr. G. H. Miles.—Salesmanship (4.15).

Salesmanship consists essentially in changing a person’s attitude towards an idea or an article: from indifference or even actual repugnance, to a desire so strong that possession alone satisfies.

This is mainly an affective change and involves many psychological factors.

The ways and means by which such changes can be or have been effected, form a group of facts which constitutes the Science of Salesmanship.

The correct application of these facts constitutes the Art of Salesmanship.

The salesman must be able to approach the buyer so as to:

i. Find what interests and desires will be accentuated by possession of the article.

ii. Develop in the person a feeling of dissatisfaction within this region of his personality.

iii. Show how the article or idea, and it alone, can satisfy the need.

To take up a new outlook or point of view or to acquire some additional material possession involves some degree of sacrifice. This is generally accompanied by resistance.

The salesman must:

(a) Avoid or lessen the building up of this resistance.

(b) Overcome it by developing around the idea or article a strong emotional appeal.

What psychological methods can be used to determine whether and in what degree a potential salesman possesses this ability to meet these and similar situations?

Friday, September 3.

Presidential Address by Dr. Mary Collins on Tests in common use for the diagnosis of colour defect (10.0).

Dr. P. E. Vernon.—Personality questionnaires and factor analysis (11.0).

The paper describes the many questionnaires or inventories which have been constructed, chiefly in America, in the attempt to measure personality.
traits such as emotional adjustment, introversion, sociability, self-assertion, etc. They contain lengthy series of intimate personal questions bearing on these emotional traits. It is shown that the attitude of the subject towards the test and the investigator, his conscientiousness or suspicion, also his unconscious resistances, his suggestibility, and his degree of awareness of his own emotions, greatly affect the responses that he makes. Hence the validity of the quantitative results which the tests yield is generally poor. They may however sometimes be of qualitative value to the clinical psychologist, e.g. as a starting point for an interview.

One of these questionnaires, devised by Dr. Boyd to measure nineteen traits or personality tendencies, was applied to men and women at a training college. When the results were studied by Thurstone's multiple factor analysis technique, it was found that the nineteen tendencies overlapped very greatly, and could be reduced to four more general independent tendencies, which seemed to correspond to:

2. Care-freeness.
3. Scrupulousness.
4. A sex difference factor.

A discussion is given of the psychological significance of these factors.

Dr. W. Brown.—Hypnosis, suggestibility and progressive relaxation (12.0).

1. Clinical and experimental evidence continues to add to our knowledge of the nature of the hypnotic state, and of its relation to sleep on the one hand, and to suggestibility on the other. Conditioned reflexes appear to be readily produced in hypnotised subjects, and the therapeutic effects of prolonged suggestion treatment may be in part explained in terms of the building up of new conditioned reflexes by a repetitive process. But the fact that a single treatment of brief duration may sometimes produce immediate and lasting benefit indicates that this explanation is incomplete.

2. The induction of muscular relaxation (as also the suggestion of sleep) is often an integral part of hypnotic procedure. But it is not an essential part. The beneficial effects of progressive relaxation are probably quite distinct from those of hypnotic suggestion. Nevertheless, experimental investigation on the knee-jerk, etc., shows that by the use of suggestion muscular and neural relaxation can be induced with increased rapidity and to an increased extent (as compared with non-suggestion or non-hypnotic methods). In this way great help can be given to persons suffering from anxiety states and other forms of functional nervous disorder, provided that the treatment is preceded by a certain amount of mental analysis.


4. The problems of personal influence, including those of leadership, oratory, dramatic acting and all forms of personal education and inspiration, are in essential relation with the problem of hypnotic suggestion, and prolonged psychological analysis of subjects, both normal and abnormal, is throwing increasing light upon the nature of this relationship.

Monday, September 6.

Miss M. D. Vernon.—The motivation involved in the choice of a career (10.0).

It seems likely that in general the individual's choice of a career is determined less by his specific abilities and by the qualifications which the
occupation appears to demand than by certain main underlying ‘drives’ or tendencies to action. These function in determining many other of his interests and pursuits, as well as his career. Consequently, if he be encouraged by suitable questions to describe these pursuits and his reason for following them, as well as for his choice of career, his replies and his manner of answering may throw some light indirectly upon the nature and functioning of these drives. This paper describes an inquiry made along these lines by interviewing women University students.

Symposium on How people compensate or adjust themselves for lack of ability (10.45).

Mr. T. A. Rodger.

Dr. E. Miller.

Dr. John Rickman.—The processes governing psychical compensation.

If ‘outlet’ is blocked in one direction there is a ‘compensatory’ development in another direction—granted. But what are the causes of the blocking? Are they always external or environmental or is the deflection of interest sometimes, perhaps more commonly, internal, i.e. arising within the mind as a result of the interplay of inner (instinctive) forces and the environment?

Short case histories illustrating the problem.

The relation of this ‘inner blocking’ to the question of the development of culture.

Tuesday, September 7.

Dr. M. M. Lewis.—The origin and early functions of questions in a child’s speech (10.0).

A good deal of attention has been paid to children’s questions, for the light which they throw on the nature of children’s thought. The topic of the present paper is different: how does a child come to use this particular mode of speech; what is the place of questions in his early linguistic activity, and what use does he make of them?

By considering serial observations of a particular child we find that we must regard questions as a mode of action. They serve two purposes: they are (i) play, (ii) a social instrument, a means by which the child attempts to satisfy his needs. Both purposes appear throughout the following stages of development:

Stage I.—Questions first arise as a means of dealing with the present situation, that in which the child finds himself.

Stage II.—Questions begin to refer to absent situations, either past or future.

Stage III.—Questions come to refer to possible situations: they are a means of satisfying the child’s curiosity. At first he uses them chiefly as a means of corroborating the knowledge he already possesses, later as a means of adding to this knowledge.

Most discussions of children’s questions begin with this Stage III. Here we consider Stages I and II—the beginnings of questions and their early functions.
Dr. H. OLDHAM.—*Children's drawings* (10.45).

There were five main lines of research:

(a) The influence of meaning on the drawings of young children.
(b) How far drawings are typical at different ages.
(c) Sex differences.
(d) The influence of environment.
(e) The expression of emotions and unfulfilled desires in drawings.

**Conclusions:**

(a) Children cannot draw the simplest object unless it has meaning for them.
(b) The writer corroborated former research on the typical nature of children's drawings at different age levels, and made observations on the choice of subjects. In order of popularity of choice came houses, ships, motor cars, aeroplanes or trains, people, animals, flowers, still life.
(c) Houses and flowers were drawn more often by girls than boys, whilst motor cars, aeroplanes and trains were more popular with boys.
(d) The influence of environment was very strong. It was very apparent in the drawings of houses.
(e) Children from 12 to 14 were asked to express various emotions by coloured drawings. There seemed to be a fairly general agreement in form and colour in expressing the same emotion when a pattern was produced. Sometimes figures were drawn, and these were more varied.

This research is the beginning of a wider one, and may be considered as an introduction to it.

Dr. G. CALVER.—*The diagnostic and therapeutic value of play* (11.30).

(1) **Value of play to the child.**

(a) Play as development.
(b) Manipulation of material.
(c) Translation of instructive and emotional life into action.
(d) Interpretation of facts of reality.
(e) Understanding of abstract relationships by concrete material.

(2) **What we learn from child's play.**

(a) Normal developmental phases, e.g.:

(i) Emotional.
(ii) Intellectual.
(iii) Sense of reality.

(3) **As expression of abnormalities.**

(a) Family and other environmental situations dramatised.
(b) Emotional disharmonies. Fear; anxiety; insecurity; aggressiveness.
(c) Early psycho-neurosis. Hysterias; obsessions; sexual aberrations.

(4) **Play methods used for diagnosis.**
(5) **Play as a therapeutic agent.**
Dr. G. Seth.—The development of infant behaviour: a study of the responses of infants from 20 to 52 weeks in age (12.15).

Afternoon.

Dr. P. B. Ballard.—Intelligence tests and secondary school entrance examinations (2.0).

Mr. T. E. Stubbins.—Prognostic value of school examinations (2.45).

In an attempt to determine which part of an Entrance Scholarship Examination most successfully predicted success in a School Certificate Examination, coefficients of correlation between each part of the former and nine subjects taken by the same (180) pupils in the latter were obtained. Owing to the existence of intercorrelations between the parts of the Scholarship Examination, these coefficients lead to conclusions of doubtful value. Regression Equations, in which allowance is made for such intercorrelations, were therefore worked out.

The equations are of the form:

\[ x_1 = ax_2 + bx_3 + cx_4 + dx_5 + k \]

where \( x_1 \) represents a candidate's score in a School Certificate subject

\( x_2, x_3, x_4, \) and \( x_5 \) the same candidate's marks in the various Scholarship subjects,

\( k \) is a constant,

and \( a, b, c \) and \( d \) are the regression coefficients, being the weights to be assigned to the appropriate scholarship mark.

A high positive weight indicates that the corresponding Scholarship mark has high predictive value in the School Certificate subject denoted by \( x_1 \).

A coefficient of multiple correlation gives the relationship existing between the marks gained in the School Certificate Examination and those which would be obtained by substituting his Scholarship marks in the equation.

The entrance examination was of interest, in that it comprised attainment tests in English and Arithmetic, an Intelligence Test, and estimates submitted by the Headmasters of the Elementary Schools attended by the pupils.

Dr. D. A. Walker.—Answer-patterns (3.30).

It is a fact well known to examiners that the nature of a test paper determines to a certain extent the way in which scores in the test will be distributed. The nature and extent of this predetermination of score-scatter by the type of paper set has been the subject of the investigation reported in this paper. So far the research has been confined to tests where each item carries unit score. It is then possible to construct for each test an answer-pattern, which is a table of the frequencies of correct answers to the various items, these being placed in order of difficulty. In the particular case where each candidate's score is made up of answers to the easiest items, it can be shown that there is an exact relationship between the answer-pattern and the score-scatter of the test. In the more general case there still persists some measure of relationship, and this has been studied by experimental methods. A particular case of this relationship is the production by a difficult test paper of a positively skewed score-scatter, spacing out the best candidates.
SECTION K.—BOTANY.

Thursday, September 2.

Presidential Address by Prof. E. J. Salisbury, F.R.S., on The modern study of plants in relation to education (10.0).

Sir Arthur W. Hill, K.C.M.G., F.R.S.—The Botanic Garden, Buitenzorg, Java (11.5).

Prof. Dr. A. J. Kluyver.—On the luminescence of bacteria (11.15).

A report on some results obtained by a biophysical research group, under the direction of Ornstein and Kluyver, in investigations on the luminescence of bacteria. The aim of the work is to get a general insight into the factors which determine the emission of visible light by luminous cells. In the first place careful quantitative determinations of the energy distribution over the various wavelengths were made. The results led to the conclusion that to all probability the spectrum emitted may be reduced to two symmetrically broadened fundamental frequencies. A study of the spectra of two different chemoluminescent reactions, proceeding in an aqueous medium, yielded analogous results, partly the same frequencies being encountered. Moreover an analysis of the fluorescence spectrum of flavin showed that this spectrum may be considered as one symmetrically broadened fundamental frequency, this being one of the fundamental frequencies present in all bioluminescence spectra studied. This result offers an indication that flavin, a compound of quite general occurrence in living cells, may in some way be connected with the light emission.

Secondly, experiments were made in which the influence of various poisons both on oxygen consumption and on light emission was studied. By adding suitable quantities of cyanide to the medium, a region was found in which the light emission is linearly dependent on the oxygen consumption, thus giving definite proof that, in agreement with a widely spread assumption, oxygen indeed takes part in the process which ultimately is responsible for the light emission.

Also this result points to the co-operation of flavin, as a component of the yellow respiratory enzyme, in the light emitting reaction.

Dr. M. J. Sirks.—Plasmatic inheritance (11.45).

By the very impressive character of Morgan’s theory of genes as localised in the chromosomes, the majority of geneticists have been led to confine their attention to the rôles of the genes, while the plasm is entirely neglected. Those geneticists forget that the genes as such can show their action in the phenotype only by means of the plasm instrumentality. A number of cases have been observed in which the plasm plays a rôles as a counterpart to the genes. These results may be grouped as follows:

1 an afterworking by the nature of the eggplasm whereby in the embryo characters are fixed before the newly constructed genotype of the fertilised nucleus can show its influence (Correns, Matthiola; Boycott, Limnaea);
2 an entirely independent action of the plasm in the production of characters without any influence of the genotype (chlorophyll; Wettstein, mosses; Schlösser, osmotic values);
(3) difference in reaction by different plasms on the same genotype (permanent or transitory) (Sirks, *Vicia Faba* and *Phaseolus*; Lehmann, *Epilobium*; Schlosser, tomatoes);
(4) elimination of zygotes or gametes of definite genotypical constitution under influence of the plasm (Sirks, *Vicia Faba*; Bateson, Chittenden, Gairdner and Pellew, flax; Skalinska, *Aquilegium*).

A further problem is the question if the plasmatic nature can be changed by the genotype or not; though the majority of studies point to the negative answer, this problem is still unsettled.

Dr. S. Williams.—*An examination of the evidence used in phylogenetic problems* (12.15).

The evidence used in the quest of Phyletic Lines may be classified under the heads of (a) the comparative morphology of living plants, (b) taxonomy, (c) the comparative morphology of fossil plants, (d) the historical record afforded by the fossils, and (e) plant distribution. To these there may be added lines of research which, so far, have yielded relatively few data relevant to phylogenetic problems, viz., experimental morphology (including certain aspects of autecology), statistical studies, and cytogenetics.

The validity of this evidence, apart from the historical record of the fossils, has been repeatedly called in question. The validity of the evidence from the fossil record is, however, generally accepted, but the fragmentary nature of it has been repeatedly stressed. Few critics have gone so far as Lotsy who, in 1916, stated that ’Phylogeny . . . . is no science, but a product of fantastic speculations,’ but many have adopted a less extreme although still critical attitude. On the other hand, many morphologists have maintained, or have returned to, a belief in the validity of the evidence taken as a whole. All will agree that the phyletic problem still exists.

The major problem is clearly as to whether the canons of comparative morphology, as applied to living plants, to the fossils, or to cytological facts, are scientifically sound and likely to lead to conclusions possessing a reasonable degree of probability. ’The fossil record provides a useful, though usually inadequate, check on the results derived from comparative methods. An extremely important question is as to whether cytogenetics can be developed as a test in broad phyletic problems, thus extending the useful results already attained in relation to the more limited, but cognate, problem presented by the interrelationships existing within small taxonomic groups.

A general discussion of the present position of phyletic morphology, contributed to by specialists in the various fields of research mentioned above, might prove of great value in defining the modern attitude to Phylogeny and in indicating fruitful lines for future research.

**Afternoon.**

Excursion to Gotham and the West Leake hills.

**Friday, September 3.**

*Joint Symposium* with Section D on *Recent work in genetics and cytology* (a non-technical presentation designed in particular to interest those not working on cytology or genetics). (10.00)

Chairman: Prof. F. A. E. Crew.
Prof. Dame Helen Gwynne-Vaughan, G.B.E.—Incompatibility (10.0). (Openers of discussion: Dr. M. J. Sirks, Mr. W. J. C. Lawrence and Dr. M. A. P. Madge.)

It has long been recognised that particular matings may fail, even when the sexual apparatus is efficient and the gametes are able to function in other unions. Often, in organisms with both male and female cells, self-fertilisation, though not mechanically prevented, proves rare or impossible. Such forms are said to be self-incompatible. Incompatibility may extend beyond the individual to the variety or group of varieties; a condition of cross-incompatibility then exists. This state of affairs has been little studied in animals, though it has been recognised in the sea squirt. In higher plants, and especially in fruit trees, it is well known and has been shown to depend on appropriate genes. In fungi, also, incompatibility is determined by the nuclear content of the cell; it is here associated with the disappearance of normal fertilisation and with the problems incidental to the invasion of the land. Incompatibility, like the separation of male and female organs in different individuals, is a means of ensuring exogamy.

Prof. F. A. E. Crew.—The genetical aspect of crossing over (10.45). (Openers of discussion: Prof. R. A. Fisher and Dr. F. W. Sansome.)

Dr. C. D. Darlington.—Mechanism of crossing over (11.20). (Opener of discussion: Dr. P. C. Koller.)

Two important changes take place at meiosis: first, reduction in the number of chromosomes by the segregation of partners, and secondly crossing-over between those partners. Crossing-over takes place as a result of a torsion developed in the paired chromosome threads. This torsion twists the threads round one another until an equilibrium is reached like that in spun wool. The chromosomes divide, the equilibrium is upset and the daughter threads break at opposite points, untwist and rejoin: crossing-over has taken place.

The result of the division of the chromosomes is that the partners fall apart, attraction being limited to pairs. The result of their crossing-over is that the partners are nevertheless held together at the points of crossing-over or chiasmata. All the later association of the chromosomes and hence their segregation and reduction depends on these chiasmata.

Crossing-over has always been understood to perform the useful but not indispensable function of recombining hereditary differences in sexual reproduction. We now learn that it underlies sexual reproduction itself, for without crossing-over the necessary reduction and segregation of chromosomes cannot take place.

Mr. E. B. Ford.—Genetical control of development (12.0). (Opener of discussion: Dr. J. S. Huxley.)

Afternoon.

Miss G. N. Davies.—The effect of zinc sulphate on dwarf French beans (2.15).

In connection with water pollution by lead mines in which zinc is also present, a series of culture experiments has been carried out to ascertain
the effect of zinc sulphate on Dwarf French Beans. The plants were supplied with varying concentrations of zinc sulphate ranging from one to 200 parts per million, ten to fifteen plants being used for each concentration. Conclusions were drawn from the appearance of the plants throughout the experiments, and also from the dry weights of the plants at the end of the experiments (twelve weeks). All experiments showed that the average dry weight of the plants decreased as the concentration of zinc sulphate increased. Plants were, however, able to survive for twelve weeks in concentrations as high as 50 parts per million, although they appeared to be unhealthy. This is significant, as the concentration of zinc in this locality is never as high as 50 parts per million.

Dr. Winifred E. Brenchley.—Recent work on boron in relation to plant disease (2.35).

The importance of boron in the control of certain forms of plant disease is now widely known, and the results of tests in many parts of the world are being recorded with increasing frequency, from the scientific as well as from the commercial aspect.

The occurrence of heart rot in sugar beet was first noticed at Rothamsted in 1935, the earlier sown crops being the more severely attacked. In the autumn a number of healthy and diseased plants were transferred to sand cultures with adequate nutrients, some receiving light or heavy dressings of boric acid and others none. In the absence of boric acid the characteristic signs of boron deficiency appeared in the shoots, the apices of the stems and the flower buds blackening and dying. This occurred even when no symptoms were present before transplanting. In the presence of boric acid all plants produced healthy shoots, with no deficiency symptoms. Where heart rot was originally present and the main axis killed, a number of healthy, lateral shoots were produced. The later addition of boron did not improve the condition of the roots of affected plants, as irreparable damage had been done before transplanting.

The ability to produce healthy shoots in the second year from affected roots may be important for seed producers, if the use of small amounts of boron compounds after the presence of the disease is recognised renders seed formation possible.

Miss I. M. Wilson.—The ascii of Peziza rutilans Fries. (2.55).

Peziza rutilans is a Discomycetous fungus in which sexual organs are absent. The ascus is formed, as in many other Ascomycetes, from the binucleate, penultimate cell of the crozier. Fusion of these two nuclei takes place during the early stages of ascus formation. Successive crops of asci are formed by the proliferation of the crozier.

The first two divisions in the ascus constitute a meiotic phase. Sixteen bivalents are present in the prophase of the first division and sixteen longitudinally split V-shaped chromosomes pass to each pole in the anaphase. In the prophase of the second division sixteen similarly split chromosomes reappear, and in the anaphase sixteen V-shaped chromosomes travel to each pole. The third division in the ascus is a mitosis. Sixteen V-shaped chromosomes are found in the prophase and metaphase; they split longitudinally and sixteen V-shaped chromosomes pass to each pole during the anaphase.

Sixteen V-shaped chromosomes are also present in the divisions of vegetative nuclei and in the two nuclei which undergo a simultaneous mitosis in the crozier of the ascogenous hypha.
It is believed, therefore, that in the life-history of this fungus there is one nuclear fusion, namely that in the penultimate cell of the crozier, and the compensating reduction of the chromosome number occurs in the first of the three divisions in the ascus.

Mr. C. G. Chesters, Mr. H. E. Croxall and Miss K. M. Keene.—On certain fungi having a Libertella imperfect stage (3.15).

After a brief review of the characteristics of the Allantosphaeriaceae von Höhnel, illustrated by references to species of the genera commonly occurring in Britain, certain species of Diatrype, Eutypa, Diatrypella and Anthostoma are described in greater detail. Special attention is paid to the structure of the stromata and the development of the imperfect stage both on typical host substrata and on agar media. It is shown that a Libertella stage has been developed in single ascospore cultures of the majority of the species studied and that similar Libertella spores have been collected in association with the ascophorous stage on naturally infected hosts in certain instances. Some species have also a Maemospora stage occurring on the same mycelium as the Libertella; this is considered to represent a microconidial condition. The importance of the similarity of the imperfect stage in the several genera of the Allantosphaeriaceae is emphasised and its bearing upon the relationship of these genera with certain other Pyrenomycetes is discussed.

Mr. A. E. Vinss and Dr. A. H. Campbell.—A physiological effect of Lophodermium macrosorum on the needles of Picea excelsa (3.35).

In a Spruce the needles usually fall rapidly should the shoot bearing them be damaged or cut from the tree. Abscission takes place at the junction of needle and peg, leaving the bristle-like peg attached to the shoot. When Spruce needles are infected by Lophodermium macrosorum, it is noticeable that they cannot be easily detached even after the shoot has been cut from the tree for several months. If such needles are pulled from the shoot the peg will invariably be detached as well. It is evident that the fungus prevents the proper functioning of the abscission mechanism situated between the needle and the peg. It can be shown that abscission is brought about by water loss from the needle causing a hygroscopic contraction of the base. This contraction is greater than the contraction of the peg tissues, with the result that stresses are set up which ultimately bring about abscission. To operate this mechanism it is essential to have a considerable and rapid water loss from the needle. Infected needles are provided with a black ring or zone of fungal cells at the base and with mycelial aggregations which block the stomata. It can be shown experimentally that the fungal plates together with the sub-stomatal sclerotia effectively diminish water loss and hence prevent the abscission mechanism from functioning although the needle may have been dead for some time.

Dr. N. T. Gill.—Observations on the viability and dormancy of weed seeds (3.55).

Our knowledge of the stage of development at which seeds of various plants become capable of producing a new plant is not very considerable. This knowledge is of some practical importance; therefore observations have been made on the germination of seeds collected from plants cut down at various stages of growth.

In some cases plants cut down in the flowering condition ripen seed
capable of germination later when conditions are suitable. The problem is complicated by the fact that in the case of most weed seeds little is known of the length of the resting period of normally ripened seeds. For this reason it has been necessary to study the resting periods of the seeds of the various weed species together with the first problem.

**Semi-popular Lecture by Dr. M. A. H. Tincker on Growth-promoting substances and horticulture (5.0).**

Investigations by Went, Kögl, and others led to the isolation and chemical recognition of the plant hormones, auxin \( a \) and \( b \). Hetero-auxin, \( \beta \)-indolyl acetic acid, associated in certain animal products with the former substances was also observed to influence the growth of plants. This more readily available, simpler chemical may be applied to plants as a paste using lanolin, or in solution in water. Many compounds have been tested by Zimmerman and others; \( \alpha \)-naphthalene acetic acid is highly active at great dilution.

\( \beta \)-indolyl acetic and \( \alpha \)-naphthalene acetic acid induce the formation of roots.

For vegetative propagation they are now used in practical horticulture to facilitate and accelerate the development of roots from cuttings, herba-

ceous and woody. Roots are developed more rapidly in greater numbers on each cutting, whilst the number of cuttings which form roots is con

siderably increased by these growth substances. Many species and varieties have been tested and showed these responses, which vary in quality according to the season of treatment and the correlated nature of the material chosen.

The chemicals are taken up conveniently by leafy cuttings, placed with their basal ends in a solution for twenty-four hours.

Roots may develop some small distance from the point of application of the chemical. Inhibition of foliar development frequently results if cuttings are taken before the buds have opened. Anatomical changes result from

the stimulation including rapid cell division in meristematic tissue, cambium, in vacuolated parenchyma, and in differentiated tissue.

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**Saturday, September 4.**

Excursion to Miller’s Dale, Chee Dale and Froggatt Edge.

**Sunday, September 5.**

Excursion to Sherwood Forest and Newstead Abbey.

**Monday, September 6.**

Discussion on Genetics and taxonomy (10.0).

Dr. W. B. Turrill.—The expansion of taxonomy.

(1) *Introduction.*—The necessity and practical aims of classification.

(2) *Alpha taxonomy.*—Its methods, achievements, continuation, and limitations.

(3) *Omega taxonomy.*—The new ideas and ideals. The introduction of

experimental methods. The reactions between taxonomy and
cytology, ecology, and genetics. The advantages and dangers of the new outlook.

(4) The practical aims of the Association for the Study of Systematics in Relation to General Biology.

Mr. W. J. C. Lawrence.—*The genetics and taxonomy of some garden plants* (10:30).

As a result of recent biochemical and genetical investigations on flower colour in a number of species, the basis of floral pigmentation is now clear.

(i) Biochemical.—The three primary classes of pigmentation are: (1) plastid (pale yellow to orange); (2) anthoxanthin, i.e. flavones and flavonols (ivory to deep yellow); (3) anthocyanins (reds and blues). A true ‘white’ lacks all three kinds of pigment. The anthocyanins may be further divided into three main types—pelargonidin, cyanidinin and delphinidin. The wide range of flower colours results from the combination in various proportions of the different pigments.

(ii) Genetical.—The role of the genes in pigment production is as a rule highly specific, a given gene acting upon a particular pigment, either quantitatively (increase or decrease in production) or qualitatively (modification, within the class, of the nature of the pigment).

Experiments on three garden plants, *Streptocarpus*, *Delphinium Ruysii* and *Dahlia variabilis*, demonstrate how the origin of species may be elucidated from combined cyto-genetical and biochemical analysis. The hybrid derivatives show, chemically, recombination of the pigments of the parent species. The methods employed enable rapid and precise comparisons to be made between species, thus providing the taxonomist with a further measure of the relationship and evolution of species.

Prof. J. R. Matthews.—*Specific segregation and distribution* (11:0).

Examples are given of closely allied species which may be held to have been derived from a common ancestral stock but which, among other features, are distinguished by a different geographical range. In the absence of genetical studies the origin of these related forms is still obscure, though cytological observations are available for some of them. Little attempt has yet been made to formulate views regarding the influence of isolation.

Dr. T. J. Jenkin.—*The relation between genetics and systematics* (11:30).

This question is discussed primarily as it applies to some of the non-cereal grasses.

In these grasses, the paucity of well-defined and easily observed morphological characters makes the work of the systematist, and that of the geneticist, very difficult. This may have led the systematist to attach undue importance to those characters that are easily observed, so that detailed classification is sometimes based upon somewhat obscure and possibly inconstant characters.

The geneticist is not always a good systematist, neither is the systematist always an experienced geneticist, so that clearly collaboration is greatly to be desired. This applies equally to the question of supposed natural hybrids, but perhaps here the plant breeder and the cytologist are more important than the pure geneticist.

The artificial production of inter-specific and inter-generic hybrids will affect not only the position of the supposed natural hybrids, but also the
function of systematics in relation to such plants. Finally, we must consider how the new methods of plant breeding, genetical studies and cytology will affect our conception of a natural system of classification, and the determination of phylogenetic relationships.

Dr. J. W. Gregor.

General Discussion on Genetics and taxonomy (12.0).

Miss M. L. Green.—The evolution and recent progress of botanical nomenclature (12.30).


Afternoon.

Dr. G. Bond.—Uptake of fixed nitrogen from Leguminous root nodules by the host and by other plants (2.15).

Experiments are described which aimed at the detection of excretion of nitrogenous substances from the root nodules of the following leguminous types: Soy Bean, Broad Bean (Vicia Faba L.), Forage Lupin (Lupinus sp.) and Pea (Pisum sativum L.). The plants were grown in sand cultures, initially sterile, the nitrogen content of the sand being subsequently determined by the Kjeldahl process. With the first three types the increase in nitrogen content of the sand was negligible, and only slight with the Pea. These results were confirmed by other experiments in which non-legumes were grown in the same pots as nodulated legumes, no benefit being derived by the former. It is concluded that excretion is not a regular accompaniment of fixation in root nodules. The importance of the structure of the peripheral nodule tissues is stressed.

Dr. S. Williams.—The morphology of the rhizophoric parts of living Lycopods (2.35).

The rooting systems of most of the living Lycopods are anomalous and this is particularly so in the Ligulatae. The genus Selaginella shows two distinct types, viz., that of S. spinulosa with its basal knot and that of the
dorsiventral species. The rhizophores of the latter type have been the subject of much discussion and it has been concluded on general morphological grounds that they are organs *sui generis*; experimental evidence has tended to show that they, and particularly the angle-meristems from which they arise, are indifferent structures capable either of forming roots or of being converted into leafy shoots. The organisation of the stock of Isoetes has also been repeatedly discussed. The rhizophoric region consists of the basal part of the stock which possesses two or three stelar lobes with a line of meristem running along the lower edges of these. These anomalous rooting systems are of particular interest for comparison with those of the fossil Lycopodiales.

Prof. J. Walton.—*The morphology of the rhizophoric parts of the extinct Lycopods* (2.55).

Fairly close comparisons based on external features may be made between the root-bearing stocks of *Stigmaria, Pleuromeia, Nathorstiana* and *Isoetes*. There are structural peculiarities at the base of the aerial stem of *Lepido-phloios wuschianus* Carr. and *Lepidodendron saalfeldense* Solms which suggest further comparisons with *Isoetes*. In *Selaginella spinulosa* the basal knot may be compared with the rhizophoric parts of *Stigmaria* and *Isoetes*, but no corresponding structure is found elsewhere in the living Lycopods. There is nothing comparable to the rhizophore of *Selaginella* (excluding *S. spinulosa*) in the fossil Lycopods.

Prof. T. M. Harris.—*Naiadita, a strange fossil Bryophyte* (3.15).

*Naiadita lanceolata* is a very common fossil in the English Rhätic and has been recognised as a zone fossil for ninety years. It consists of a slender parenchymatous axis bearing unicellular rhizoids and lanceolate leaves, arranged in a $\frac{2}{3}$ spiral. The leaves have a well-marked apical cell but no midrib. The axis usually terminates in a conical gemma cup; the gemmæ are multicellular and germinate directly (i.e. without a protonema stage). The antheridia are still undiscovered. The archegonia are borne laterally and are at first sessile and naked but afterwards a perianth of about four leaves grows round them and the whole is carried up by a pedicel. The sporophyte consists of a spherical capsule and a small hemispherical foot embedded in the pedicel: there is no seta. The capsule is cleistocarpic; its wall is composed of a single layer of evenly and thickened square cells. The capsule has no columella nor elaters but only spore tetrads. There is some evidence that *Naiadita* was a submerged water-plant.

All organs of *Naiadita* are typically bryophytic, but its further classification is only possible if some considerable general assumptions about Bryophyte morphology are made. On Wettstein's view of gametophyte reduction, for example, *Naiadita* could be regarded as one of the *Sphaerocarcales* and closely related to *Riella*.

Miss A. Bennett.—*The ecology of the limestone pavements at Hutton Roof and Tarleton* (3.35).

The vegetation of the limestone areas depends largely upon the configuration of the ground and falls into three main groups: (1) Pavements; (2) Escarpments; (3) Screes. The associations developed are regulated by exposure to weather conditions and the angle of slope, which together control accumulation of soil and pH value. Grazing by animals causes
much of the vegetation to remain at the subclimax (or disclimax) stage. Recolonisation takes place and some retrogression is also in progress.

Glacial drift overlying the limestone has introduced many calcifugous species and local topography permits the invasion of the limestone by natives of siliceous soils. An intimate mixture of plants occurs on both formations and species which differ widely in their soil requirements exist in the same soil pocket. Some plants which are normally regarded as calcifugous occur in the talus of the limestone scree.

Certain species are restricted in their distribution, some are widely dispersed throughout a county and others are confined to one or two stations in some areas and are abundant in similar formations only a few miles distant.

**Tuesday, September 7.**

**Joint Discussion with Section M on Pasture problems (10.0).**

**Sir John Russell, O.B.E., F.R.S.—The general nature of the problems.**

The problems of grass land differ in two ways from those of arable land: (1) the crop is perennial and it may remain for an indefinite number of years; and (2) the crop is a mixture of several species, often 5 or 6, but sometimes as many as 20 or 30. The perennial nature of the crop constitutes a great agricultural advantage as it obviates the need for annual preparation of a seed bed, one of the most costly items in arable farming, and it reduces to a minimum the labour of cultivation and harvesting. The fact of the crop being a mixture constitutes its chief scientific interest: grass land is one of the richest sources of ecological material in the countryside. The different species settle down to some sort of equilibrium, and for each set of conditions there is a recognisable floral type which persists so long as the conditions remain unchanged. Variation in weather conditions from year to year alter the relative abundance of the different species, particularly on land receiving no manure or only incomplete fertiliser. But the general floral type does not change. Of the soil conditions, the supply of nutrients, the reaction, water supply and air supply to the roots, and depth of soil, are all important factors. On a poor soil nothing grows vigorously and every seedling has a chance of life: the Rothamsted unmanured grass plots contain some forty or fifty different species which have settled down to some kind of equil-ibrium. Addition of plant food in the form of manure causes some of these species to grow better than others and they crowd out their less vigorous neighbours. The differently manured plots all carry distinctive floras, the outcome of this selective action. Acid conditions tend to eliminate leguminous plants: wet conditions to eliminate deep rooting grasses.

The management of the grass land introduces some important new factors. Wild grass land speedily becomes very uneven owing to the action of ants and moles, while the dead vegetation forms a mat which, if not removed by earthworms, may become a layer of peat. On well-grazed land competition for air and light disappear and the low growing wild white clover has a good chance of life. Only those taller plants survive which can continue to shoot up in spite of constant cutting. The successive new growths differ in some respects from the continuous growth of an undisturbed plant and the ageing continues, as shown by the production of more and more lignin as the season advances.

In grass land regularly laid in for hay the time of seeding becomes an important factor in survival. These factors of agricultural management
affect the flora so profoundly that initially different floras kept under the same conditions for a few years and managed in the same way tend to become indistinguishable. Grass land can always be improved by improving its management so long as the desirable plants are already there. But if they are not, the grass land must be broken up and reseded.

There are many varieties and strains of the same species of grass, and also of the micro-organisms associated with the nodules of leguminous plants. These also form part of the grass problem.

Dr. Winifred E. Brenchley.— The ultimate composition of the herbage from various seeds mixtures (10.20).

Sawyer's Field at Rothamsted was laid down to grass in 1928, being sown with six different mixtures, ranging from simple to complex. The area was grazed till 1935, and cut for hay in 1936. Estimations of herbage composition have been made regularly, the methods used being specially adapted to meet the difficulties that arose as the sward became established. At first the botanical composition of the herbage bore some relation to the seeds mixture sown, but this soon disappeared and a general levelling up occurred on all the plots. Clovers and grasses were of almost equal importance until the drought of 1933, which killed out most of the clover, its place being largely taken by grass. A certain increase of wild white clover has since occurred, but the leguminous species have failed to regain their original importance.

Summarising the present position, rye grass (Lolium spp.) has assumed and retained a dominant position, the Italian variety being particularly persistent. Cocksfoot (Dactylis glomerata) has spread rapidly, regardless of the amount sown, whereas rough-stalked meadow grass (Poa trivialis) was slow in becoming established. All the clovers have disappeared except the wild white, which shows marked seasonal variations, being specially influenced by rainfall. In general, comparatively little difference is now obvious between the herbage of any of the plots, regardless of the type of seeds mixture sown.

Mr. William Davies.— Present-day concepts of grassland improvement (10.50).

The principles of grassland improvement may be grouped as follows: (1) the botanical composition of the grassland; (2) pasture and stock management; (3) soil fertility and the means of grading up that fertility. These groups cannot be discussed singly without reference to the others because of their interdependence. Whatever is done to grassland is reflected upon that grassland as a whole. Thus alteration in soil fertility or a modification of grazing practice is bound sooner or later to be reflected in the botanical composition of the sward.

The compounding of seeds mixtures is discussed, with particular reference to simple and complex mixtures; also the place of the grass and the legume in pasture improvement, sward production and the maintenance of botanical composition. The relationship of botanical composition to the productivity and the economic value of pastures.

Strain within the species in our common grasses and clovers and methods of evaluation of strains bred for economic purposes.

The influence of sharply contrasting systems of management upon the botanical composition and the yield of pastures. The management of young leys, temporary pastures and permanent pastures. Management in relation to soil fertility and in relation to the manuring of grassland.
Mr. G. E. Blackman.—*The technique of pastureland experiments* (11.20).

For the proper study of most pasture problems some method of measuring productivity is essential; the accurate assessment of yield presents, however, a number of difficulties. In view of the profound effects that the period of grazing and its intensity may have on the sward, estimates of yield obtained by continuous cutting are liable to give misleading results. In order to simulate as far as possible grazing conditions it is necessary to carry out somewhat complex experiments. The design of these should embrace large plots to eliminate edge effects, while the replication should be sufficient to ensure that each block of plots is grazed during the major part of the experimental period and only cut for the determination of yield at infrequent intervals. Where a high degree of precision is required the stock used for grazing plots with different treatments must be kept for a preliminary period on comparable herbage. The results may also be affected by the type of stock used, and other factors dependent on seasonal differences.

Mr. Martin Jones.—*The response of plants to animal interference* (11.50).

In pastures there are various types of plants all competing for plant food. Which type succeeds best depends to a large extent on its reaction to the grazing animal.

During periods of scarcity animals are forced to eat down too hard such plants as are growing at that time, with the result that if such conditions recur frequently the most useful plants are first of all weakened and ultimately lost from the sward. Such periods of scarcity of green fodder, be it due to cold weather or to lack of moisture, generally coincide with critical periods in the life-cycle of such useful plants.

On the other hand, the protection from grazing obtained by certain other plants due to their lack of palatability enables them to increase unduly.

Left to nature the animal thus favours the least valuable plants, whereas with proper manipulation of the grazing—aiding the animal at certain times of the year and providing for it at other times—the farmer can control the destiny of his sward.

**General Discussion on Pasture problems** (12.20).

*(Concurrently with above session.)*

Mr. K. P. Biswas.—*Some observations on the aquatic and marsh plants of India and Burma* (10.0).

The aquatic and marsh vegetation of India and Burma have a very wide range of variation, dependent as they are on diverse climatic conditions in these two vast countries. The extensive open coastline harbours an interesting marine flora. The æstuvian areas stock a rich mangrove vegetation. The lagoons and inner brackish water and swamps sustain a curious mixture of freshwater and saltwater plants. The hill streams, although scarcely rich in vegetable growth, not infrequently have their beds covered with Iron bacteria, *Batrachospermum* and *Sirodotia*. Numerous freshwater lakes, tanks, pools, and puddles scattered all over the plains are storehouses of dense masses of vegetation, both Phanerogams and Cryptogams accommodating themselves in a harmonious community.
The congestion of vegetation in freshwater static waters has considerable effect on the economic life of the countries. The growth of *Eichhornia speciosa* encroaching upon the rice-fields and narrower waterways has become such a serious menace that the Government have to take recourse to legislation for its eradication. Over-abundance of vegetable growth affects the fish population, which yields good revenue to many provinces.

The general features of the plant communities, with special reference to freshwater and brackish water species, are discussed.

Prof. R. B. Thomson.—*The comparative anatomy of the male and female cone scales in the conifers (10.25).*

'Inversed' sporangial supply bundles in both male and female cone scales of the conifers have been found to vary with the number and size of the pollen sacs and of the ovules. Though the inversed bundles are abaxial in the one case and adaxial in the other, the scales are considered to be homologous structures which have become differentiated by factors associated with their function as male and female organs.

Mr. R. D. Williams.—*The frequency of chlorophyll deficient mutants in red clover (Trifolium pratense) (11.0).*

About 150 simple recessive chlorophyll deficient mutants have been identified in red clover, most of which have been shown by means of diallel crossing of the recessives or the heterozygotes to be due to different factors. The linkage relationships of many of the chlorophyll deficient factors have been studied, and ten of these have been definitely located in chromosome I, two each in chromosomes II, III and IV, and one in chromosome VI.

In order to determine the frequency with which chlorophyll deficient recessive factors occur in the heterozygous condition in red clover, two series of investigations were recently conducted—one with 22 normal green plants of the Montgomery variety and the other with 25 normal individuals of the English late-flowering variety. In the case of the Montgomery variety, 13 of the 22 plants tested were found to be heterozygous for 22 chlorophyll deficiencies—14 lethal and 8 surviving mutants, while in the case of the English late variety, 14 of the 25 plants investigated were heterozygous for 23 chlorophyll deficient recessives—11 lethal and 12 surviving genotypes.

Dr. T. J. Jenkin and Dr. P. T. Thomas.—*The breeding affinities and cytology of Lolium species (11.30).*

Inter-specific crosses between the following *Lolium* species have been attempted:

1. *Lolium italicum.*
2. *Lolium loliaceum.*
4. *Lolium remotum.*
5. *Lolium rigidum.*

The results already available are shown and very briefly discussed. The parent species and some of their hybrid derivatives have been
examined cytologically, and differences in meiotic behaviour are demonstrated by means of lantern slides.

As far as possible herbarium specimens illustrating the different types are exhibited.

Mr. J. W. G. Lund.—The algae of the margins of ponds (12.0).

The nature of the substratum of the marginal regions of certain ponds is largely dependent on the degree of exposure to which they are subjected. Where strong wave action is absent vegetable detritus can accumulate. This vegetable matter is deposited each autumn and consists mainly of fallen leaves from nearby trees and the remains of aquatic plants. In such regions planktonic, epiphytic and bottom-living algal communities occur. These communities overlap somewhat. The bottom-living community consists largely of motile forms, especially flagellates, and shows a seasonal periodicity which can be correlated with the change taking place in the vegetable detritus. This change consists in the breakdown of the vegetable organic matter with the production of a mud rich in humus. The deposits in the deeper regions of the ponds are of a different type and possess a flora dominated by diatoms. The types of flora observed are probably generally of the same nature in the littoral regions of most ponds and lakes.

Afternoon.

Exhibits (2.15—5.0).

Mr. C. G. Chesters, Mr. H. E. Croxall and Miss K. M. Keene.—Demonstration of cultures and preparations illustrating the structure and development of the imperfect and perfect stages of certain species of Diatrype, Eutypa, Diatrypella and Anthostoma.

Dr. B. Colson.—Photomicrographs of fungi.

Mr. A. D. Cotton.—A Cladophora ball from Ireland.

Miss E. M. Debenham.—Stem apices of Selaginella arenicola Underwood.

Dr. J. W. Gregor.—Experimental taxonomy.

Prof. T. M. Harris.—Naiadita, a strange fossil Bryophyte.

Sir A. W. Hill, F.R.S.—Rhododendron adenopodum.

Miss Joyce E. How.—Factors controlling the growth of Boletus elegans on gelatin media.

Dr. T. J. Jenkin and Dr. P. T. Thomas.—The breeding affinities and cytology of Lolium perenne.

Mr. J. W. G. Lund.—The algae of the margins of ponds.

Dr. M. A. H. Tincker.—Growth-promoting substances and horticulture.
Dr. W. B. Turrill and Mr. E. Marsden Jones.—Sex and flower variations in Ranunculus.

Miss E. Vachell.—Limosella in Britain.

Dr. S. Williams.—The effect of hormones on correlation phenomena in Selaginella.

Miss I. M. Wilson.—The cytology of Peziza rutilans Fries.

EVENING.

Joint Discussion, with Sections C, D, E, F, M, on Planning the land of Britain (8.0). See page 486.

DEPARTMENT OF FORESTRY (K*).

Thursday, September 2.

Hon. Nigel A. Orde-Powlett.—The present and future of estate woodlands (11.15).

The present condition of estate woodlands. Large areas totally devastated; still larger areas virtually unproductive. Their importance to the nation, particularly in time of war. Their importance in rural life. Their potential value to woodland owners.

Causes of the present deplorable condition of estate woodlands. Death duties and high taxation. Lack of interest and knowledge on the part of owners. Lack of trained foresters. Bad marketing.

Possible alternative methods by which improvement might be effected. Compulsory acquisition by the nation impracticable and undesirable. Compulsory supervision and management unlikely to produce adequate results. Voluntary improvement productive of best and most lasting results.

Means by which voluntary improvement can most speedily be brought about.

Mr. R. C. B. Gardner.—Preservative treatment of estate timber (11.45).

Mr. B. Pollard-Urquhart.—A forest working plan for the National Trust (12.15).

Afternoon.


Friday, September 3.

Mr. W. O. Woodward.—Is there a possibility of a timber famine? (10.0).

An examination of the various prophecies and statements made by distinguished scientists during the present century on the possibilities of a
timber famine. Commencing with the report of the Royal Commission on afforestation in 1906 and the subsequent warnings that have been issued about the enormous rate at which forests have been cut down and timber used far in excess of its replacement.

These warnings have not fallen on deaf ears, and much has been done to remedy this excess, but the effect of these scares has done an enormous amount of harm to those engaged in the timber trade.

Architects and engineers tend to look round for other materials in substitution of wood, believing that supplies will not always be available.

As the arguments against a timber famine are not so well known, the writer has obtained the most up-to-date information from all the large timber-producing countries as to annual cut, annual growth and re-afforestation, and the results of this survey will be summarised.

Some explanation is given of the work of Forest Products Research Boards in all important countries and the possibilities of the future will be dealt with—particularly with reference to changes in both supply and demand.

Symposium on Mining timber (10.30).

Mr. L. Holland.—Mining timber in service.

Mr. J. Macdonald.—Future supplies of mining timber from state forests in Great Britain (11.0).

Mr. J. T. Fitzherbert.—Waste of potential supplies in private woodlands (11.30).

Afternoon.

Dr. S. E. Wilson.—The pitprop situation to-day (2.15).

Mr. C. J. Jones.—Merchanting of mining timber, England and Wales (2.45).

General Discussion on Mining timber (3.15).

Saturday, September 4.

Excursion to woodland estates.

Sunday, September 5.

Excursion to Clipstone Forest (Forestry Commission) and Whitwell.

Monday, September 6.

Mr. W. R. Day and Mr. R. G. Sanzen-Baker.—Forestry problems near industrial areas (10.0).

Discussion on How the botanist can help the forester (10.45).

Mr. D. W. Young.—Introduction.

Dr. J. Burtt Davy and others.
Mr. A. C. Forbes.—The relation of macroscopic tree remains in peat to post-glacial climate (3.0).

The occurrence of pine, oak, and other stumps in marsh peat bogs, often in horizontal layers, has generally been attributed to climatic causes. Dry periods are supposed to have promoted forest growth over the bog surfaces, while wet cycles brought about its decline or destruction. Peat layers with and without tree roots would thus alternate during periods which have been termed 'Forestian' and 'Turbarian' respectively.

A careful review of all the available evidence leads to the conclusion that marsh bogs show no indication of having become either materially wetter or drier at the time tree growth established itself on their surfaces. The horizontal root development and the short intervals which elapsed before the stumps were protected by a wet peat covering from atmospheric influences definitely confirm this conclusion.

Forest growth originated and developed on a saturated stratum of partially consolidated peat until the peat-carrying roots gradually sank below the water table, and the trees succumbed. This process could repeat itself until the bog water became too acid, and only able to support sphagnum or high bog. Tree growth thus constituted a definite feature in the vegetative development of individual marsh bogs throughout north-western Europe and minor climatic fluctuations could not have affected it on all bogs at any one particular period.

Stumps under mountain or soligenous peat suggest that the tree limit previous to the peat formation above them was about a thousand feet above that of to-day. This may have been due to an increase of 3° to 4° F. in the summer temperatures, as above two thousand feet or so these temperatures are now too low for the normal development of pine in most parts of the British Isles. But a gradual deterioration in soil conditions due to leaching must also be considered in this connection. Circumstantial evidence would indicate that the present tendency is in the direction of cooler summers, stronger and more prevalent westerly winds, and milder winters.

SECTION L.—EDUCATIONAL SCIENCE.

Thursday, September 2.

Presidential Address by Mr. H. G. Wells on The informative content of education (10.0).

Discussion on Adult education (11.10).

Prof. R. Peers.—The place of adult education in the education of democracy.

1. The aims of adult education.
2. A survey of the present position of adult education in England and Wales. The machinery of administration. Numbers and types of
courses; types of students—numbers, ages and occupations; the range of subjects. A comparison with previous years in an attempt to discover trends.

3. An examination of the existing provision with a view to discovering how far adult education, in its present form, distribution and amount, is capable of achieving its aims.

4. The prospects and possibilities of adult education in relation to changing needs.

Mr. J. F. Horrabin.

Education is a social process and it must, whether consciously or not, be related to a specific social ideal. In a world where institutions and ideologies are changing, education must aim either at assisting to maintain stability or at preparing men and women for change.

Orthodox state-controlled education is designed to ensure the stability of existing institutions. It inculcates static ideas. It selects from the mass of facts which constitute 'history' those which appear to lead up to the present as the final stage of society. Any questioning of the absolute ideas or of the selection of facts so taught is (by the orthodox-minded) regarded as 'propaganda,' not education.

Real education to-day must be 'propagandist.' The educationist who pretends to be 'above the battle' is standing for the status quo in society.

Adult education, to be a live force, must serve the social needs and aims of the organised working-class movement; i.e. it must be directed towards radical changes in society.

Mr. W. E. Williams.

In a democratic movement such as adult education it is necessary to secure from time to time, in a systematic way, the views of the rank-and-file student. It is true that the 'consumer' of adult education gets his opportunity to say what he thinks at occasional branch meetings of his particular movement, but these opinions are too local and ephemeral to attain much collective value. It was for this reason that the British Institute of Adult Education, after prolonged inquiry among several hundred adult students, produced the first symposium of student-opinion about what the movement provides in certain of its classes. From the less publicised parts of this report some of the items of student-opinion are summarised; e.g. Is Adult Education provision adequate to-day? Does it unreasonably adhere to the University tradition established by Albert Mansbridge? Does it suffer by its lack of buildings, its lack of comfort and dignity? Does its practice of 'impartial' teaching blunt the cutting edge of the students' social zeal? Can it be extended or remodelled to attract the many millions who so far resist its appeal, etc. etc.?

Afternoon.

Excursion to Lowdham Grange Borstal Institution.

Friday, September 3.

Discussion on Education for the community (10.0).

Sir Frank Fletcher.
Mrs. Elsie Parker.—Education for the community in England.

The simple purpose of education. Schooling due to a conscious need for social cohesion. The emergence of England’s three-fold system of schools; does this system promote social cohesion? The distribution of opportunity; retrogression in recent years; the survival of reluctance to articulate the structure. Selection or exclusion? The notion of the ‘multilateral school.’ Immediate needs and practical reforms. The rôle of the administrator, the teacher and the parent. The need for a restatement of purpose and the stirring of social conscience.

Mons. A. Desclos.

Dr. Graefer.

Monday, September 6.

Discussion on The educational function of the university (10.0).

Sir Richard Livingstone.

If in our swiftly changing world education ceases at the age of twenty-two or twenty-three, there is every probability that a man by forty will lose intellectual energy and fail to keep up with the advancing knowledge. It is a national problem how to keep the middle-aged mentally young. Only one regimen can do this—Adult Education of a new type—and it is especially desirable for anyone holding directing posts. This is already recognised in the case of doctors’ and teachers’ ‘Refresher’ and Vacation Courses. But there is no occupation or profession in which the resumption of systematic education in later life would not be profitable; it is especially desirable and quite feasible in the Civil, Municipal and Local Authority Services. Among interesting experiments in this direction are the grant of Commonwealth Fellowships for study in the U.S.A. to Civil Servants and the recent Summer School for Colonial Civil Servants at Oxford, but they need to be widely developed. But little can be effected in this field unless the Civil Service and the Local Authorities encourage and make possible regular periods of study for their officials. The Universities’ task is to encourage and make systematic provision for such study.

The return of adult students from practical life to the University should help the study of the Social Sciences which are still very backward. They cannot be so well studied by purely academic investigators as the Natural Sciences. Civil Servants and Municipal officials, business men, doctors and others, in their different fields, are more in touch with the actual problems than is the academic researcher, and often possess a large amount of data which he cannot have. Combination in the work of research by the University investigator and the practical man could achieve results which neither can achieve separately.

Prof. M. Ginsberg.—Social science and social philosophy in the universities.

The function of the Universities in the field of social studies is clearly to equip students with the power not only of marshalling and correlating social facts but also of interpreting and evaluating them. To achieve this end social philosophy and social science must be effectively linked. Unfortunately this is rarely if ever systematically attempted. The social sciences, no doubt in the interests of objectivity and detachment, claim to be ethically
neutral. But the neutrality is illusory, since in fact the students are imbued with an amateur ethic which leaves them a prey to crude subjectivism and relativism and the fashionable dogma that value judgments merely express the needs of the dominant sections within any given community. Philosophy, on the other hand, remains aloof and ethics, in particular, is not brought into relation with actual and pressing social problems. Great changes are thus needed in the teaching of both social science and social philosophy if the Universities are to make the contribution they ought to make towards the rational ordering of society.

**DISCUSSION on Technical in relation to general education (11.30).**

Prof. H. Levy.

Mr. J. Sargent.

Mr. J. Wickham Murray.

Technical education fundamental to life.

Don't scorn material things; they must come first if we are to live at all.

How can we establish a relationship between two things which are often not understood by those responsible?

The views of those concerned in technical education in connection with general education and vice versa.

The necessity for fixing aims. The necessity for plans—local and national.

Is the content of education, technical or general, satisfactory? What is common and fundamental to both technical and general education?

**AFTERNOON.**

Excursion to the William Crane and other Nottingham schools. Leader, Mr. A. H. Whipple.

**Tuesday, September 7.**

**Report of Committee on Science in adult education, presented by Sir Richard Gregory, Bart., F.R.S. (Vice-Chairman) (10.0).**

**Joint Discussion with Section C (q.v.) on The teaching of geology in schools (11.15).**

**SECTION M.—AGRICULTURE.**

**Thursday, September 2.**

**Presidential Address by Mr. J. M. Caie on State intervention in agriculture (10.0).**

Mr. A. H. Brown.—The present economic position of agriculture (11.0).

The present economic position of British agriculture is unsatisfactory, and can rightly be described as depressed. Any industry paying wages of 8d. per hour must be called depressed.
The causes are not due to infertility of the soil, animal or plant diseases, or incompetent management. On the contrary it can be said that management generally is too good and production too great for the present level of consumption. Therefore, under-consumption is the main cause of agricultural depression. This under-consumption is the result of the low purchasing power of the masses due to low wages.

The low wage psychology that still prevails extensively among industrialists and financiers is an inheritance from the scarcity age when it was necessary to increase capital goods at the expense of consumption goods.

In a profit economy, this surplus of capital goods, i.e. ‘production kept back from consumption,' accrues to a comparatively small class, leading to waste and extravagance on the one hand, and over-investment on the other. Hence the anxiety about the foreign investment market.

For a very long period this country has been engaged in the profitable game of lending abroad. Profitable that is to certain interests. By the nature of the case these loans will be made to the so-called backward agricultural countries, who can only pay interest and sinking fund by shipping raw materials and foodstuffs to the creditor country.

These foodstuffs coming in on interest account force down prices generally and so cause distress to agriculture, and, because they are tribute goods needing no exports of manufactured goods to pay for them, are a direct cause of general unemployment, and so lessen effective demand.

Mr. A. N. Duckham.—Marketing policy and special features (11.30).

The marketing devices utilised under the Hops, Milk, Potatoes, Pigs and Bacon Marketing Schemes, the Cattle, Sugar and Wheat Subsidy, and the National Mark Schemes are outlined:—

(a) Regulation and standardisation of commercial practices (through grading services, registration of dealers, and other devices) save time, trouble and marketing costs, and broaden the basis of demand by improving quality and by facilitating the custom of new wholesale and retail buyers.

(b) Statutory combination of farmers can enhance their bargaining power and help them to obtain the price which various outlets (e.g. liquid milk, manufacturing milk) can afford to pay, instead of the price the least profitable outlet is willing to pay. Limitation of the volume of (physical) marketing and processing facilities can aid agriculture by concentrating buyers' competition and reducing their overhead expenses.

(c) Price stabilisation schemes foster efficiency by reducing the speculative nature of agriculture and help to satisfy the demand of farmers for security of livelihood (and potentially of the consumer for security of supplies and price).

(d) Protection from or limitation of imports is not alone enough to secure stable profits or increased home output, as consumer-demand may not automatically switch from imported to home-grown food. Intensive study of the consumer, and an aggressive 'sales' policy for British agriculture (sic) and home-grown food are, therefore, indicated. The relation between marketing policy and agricultural science is also discussed.

General Discussion on preceding communications (12.0).

Afternoon.

Excursion to the Midland Agricultural College, Sutton Bonington, Loughborough.
Friday, September 3.

Meeting in the River Trent Catchment Board Offices, Derby Road.

Mr. F. Yates.—Crop estimation and forecasting (10.0).

Forecasts of the yields of agricultural crops can be based either on the meteorological data or on quantitative measurements and inspection of the growing crop. The use of meteorological data requires a knowledge of the effects of meteorological factors on yield and can only take into account effects of meteorological factors. Observations on the crop, particularly quantitative measurements, may serve to integrate the effects of both meteorological and other factors. The choice of the most suitable measurements must be determined by trial.

The sampling technique developed at Rothamsted provides a method, both of estimating the average yields of the different crops promptly at harvest, and of obtaining quantitative measurements of known accuracy on the growth of the crops. During the last few years sampling observations of this nature have been carried out on experimental wheat plots at various centres, and the most suitable methods of sampling commercial yields have been investigated. Interesting results have already been achieved. More recently observations on sugar beet and potatoes have been undertaken.

The accurate knowledge of the average yields of the principal crops immediately they are harvested is of considerable importance in any controlled economic system, quite apart from its use in evolving methods of forecasting.

Mr. W. H. Haile.—Drainage system of the Trent Catchment Area (10.45).

Principal H. G. Robinson.—The agriculture of the district (11.30).

The district discussed is that within a twenty miles radius of the city of Nottingham, and concerns the central portion of the Trent valley. It is an area in which the interests of agriculture and industry clash in respect of labour demands, but the industrial population has provided good markets which have had a marked influence on agricultural systems.

Mixed farming is typical—indeed it is the most typical mixed farming district in the country. The distinctive soil types introduce variations in the farming system. The Bunter soils constitute a major agricultural problem in this district, chiefly because of the low and uncertain rainfall. The Keuper Marl provides a sharp contrast, giving rise to heavier and more fertile soils. The Trent valley alluvial soils are often underlaid with gravel, while the Coal Measures give rise to a system of agriculture that flourishes because of good markets as distinct from a good farming environment.

There are interesting historical associations, including Laxton, the only surviving example of open-field farming, while Robt. Bakewell was a native of the district.

Present-day farming in the district concerns the production of milk as the dominant activity, even on the small farms which are typical of the area. On the arable side wheat and oats are the principal cereals, while of the roots potatoes and beet find an important place in the rotation.
Mr. H. T. Cranfield.—\textit{Liming and soil fertility: is a planned scheme desirable?} (12.15).

The problem of liming the soils of this country has attained prominence recently by the decision of the Government to subsidise the purchase of lime by farmers, as part of a scheme for increasing soil fertility.

We have many thousands of acres of land which are in urgent need of lime, and, moreover, will require systematic liming if their crop-producing powers are to be maintained. In Nottinghamshire alone the area of land suffering from soil acidity is very considerable.

If any campaign designed to stimulate increased liming of soils, many important factors must be given due consideration. Indiscriminate liming may lead to wastage and in many cases very disappointing results. Liming alone may be ineffective unless accompanied by good farming and adequate manuring. This applies equally to grassland as to arable land. Over-liming must be avoided, having regard to losses by drainage and to the possibility on some soils of certain deficiency diseases of crops appearing.

It is urged that complete success of a liming campaign can be reached only by the formulation and development of a scheme whereby all farmers in lime-deficient areas will be strongly urged to seek expert advice before arriving at any decision regarding the liming of their land. If such a scheme were taken up wholeheartedly, the present county and provincial advisory services would be inadequate to deal efficiently with the increased demand on their services and an increase in personnel would be indicated. The expenditure necessary would be small relative to the sum of money which the Government has earmarked for liming during the next few years.

\textbf{Afternoon.}

Excursion to Laxton ‘open fields,’ Kirklington Hall and Brackenhurst Hall, Southwell.

\textbf{Saturday, September 4.}

Excursion to Lincolnshire, Kirton Agricultural Experimental Station, Fleet, Spalding. Boston, including visit to Captain Wilson’s farm at Surfleet to see intensive vegetable cultivation and the Indore method of making humus; visit to a typical Fen farm; visit to Kirton Experimental Station.

\textbf{Monday, September 6.}

Mr. H. V. Taylor.—\textit{The development of horticulture in glasshouses and frames} (10.0).

Plants indigenous to a country are those suitable for production in the climate enjoyed by that country, but where it was desired to grow other plants it became necessary to construct suitable houses and frame structures for their protection. When such production of plants in glasshouses and frames started is not clear, but it was probably practised on the Continent long before the system came to England. There can be no doubt, however, that Sir Joseph Paxton was largely instrumental in popularising the building of glasshouses, first by his erection of the Conservatory at Chatsworth and
secondly by his erection of the Glass Palace in Hyde Park to house the International Exhibition in 1851. After this the popular conception of glasshouses was much widened and industries of crop production sprang up at Swanley, Worthing and North London in glasshouses, since which time the industry has very much increased.

Glasshouses and frames are now used for the production of early vegetables and salads, flowers and fruits, and are extensively used in the production of tomatoes.

The heating of these glasshouses and frames has also gone through stages of development from the use of fermenting tan pits, flues in the walls, steam jets, to hot-water tanks circulating hot water in pipes; coal, coke, oil and electricity have all been used as heating fuels. The process of development and evolution still continues.

Dr. W. F. Bewley, C.B.E.—Science in relation to the glasshouse industry (10.30).

During the early days of the glasshouse industry some fifty to thirty years ago, crops were grown more naturally than they are to-day, when 'out of season' crops and those planted unusually early yield the greatest profits. With the coming of early forcing and heavy feeding came a multitude of diseases and pests which soon caused serious financial losses.

To combat these enemies the Experimental and Research Station was started at Cheshunt in the centre of the great Lea valley glasshouse district. This paper represents an attempt to show how the scientific workers studied the problems year by year, solving each in turn, and by recommending measures which the practical grower could use safely and easily removed the menace of financial ruin from the industry.

Mr. A. W. White.—Bulbs under glass (11.0).

Daffodils and tulips are the principal bulbs dealt with, although there are many other classes, e.g. Iris and Gladioli, which may be discussed. The important part of the subject deals with the treatment of the bulbs prior to taking them into heat. The actual forcing under glass is not nearly so important as the preparation, both in the growing and the storing previously. Lifting, grading and storing are great factors in the preparation for bulb forcing, and it is on these operations that the results so much depend. After that comes the boxing, and still further care is necessary so that the bulbs may get their proper root action.

Consideration is given to the various varieties of both Daffodils and Tulips that may be prepared for Christmas and New Year flowering, with notes upon the class of house in which they are forced, and the temperatures used. Then come the easier methods of obtaining successful crops for mid-January and February, and reference is made to preparation and gentle forcing for March and April flowering.

Bulbs planted in cold frames are considered.

Mr. F. A. Secrett.—The production of early vegetables and salads under glass (11.30).

This subject is of universal interest because the health of nations and individuals is seriously affected by the correct production of vegetables which are so necessary in the well-balanced diet.

During the past few years horticultural duties have tended to stimulate
the production of early vegetables under glass, but there is still room for expansion in this particular section of the agricultural industry. Certain factors and conditions govern successful production, and these are, briefly:

1. Soil and situation.
2. Manure and cultivation.
3. Water supply.
4. Soil-heating.
5. Labour.

The crops dealt with in the paper are: cabbage lettuce, cos lettuce, mint, carrots, turnips, marrows, cauliflowers, beans, spinach, celery and melons; but it must be noted that, as more knowledge is acquired by further experimental work, many additional crops will be grown under glass.

**General Discussion of preceding communications (12.0).**

**Tuesday, September 7.**

**Joint Discussion,** with Section K (q.v.), on Pasture problems (10.0).

**Evening.**

**Joint Discussion,** with Sections C, D, E, F, K, on Planning the land of Britain (8.0). See page 486.
CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES

The Conference was held at University College, Nottingham, on Thursday, September 2, and Monday, September 6, 1937, under the presidency of Professor James Ritchie.

A large audience attended the meetings in addition to delegates representing seventy-five societies.

Thursday, September 2.

Dr. Tierney, Secretary of the Conference, reported that nominations were required to fill two vacancies on the Corresponding Societies Committee in place of Sir Albert Kitson, deceased, and Mr. T. Sheppard, who retires by seniority. A cordial vote of thanks was accorded to Mr. Sheppard for his valued services and the delegates approved the following recommendations to Council as members of the Committee for the ensuing year:

Prof. J. Ritchie.
Dr. Vaughan Cornish.
Mr. T. S. Dymond.
Prof. W. T. Gordon.
Dr. A. B. Rendle.
Dr. G. F. Herbert-Smith.

The delegates appointed the following representatives to the Committee of Recommendations: Prof. J. Ritchie and Dr. C. Tierney.

ADDRESS ON THE OUTLOOK OF NATURAL HISTORY

By Prof. James Ritchie,
President of the Conference.

THE NATURAL HISTORY OUTLOOK IN LOCAL SOCIETIES.

You as the elected representatives of the Corresponding Societies stand for that love of Nature and inquisitiveness about natural phenomena which have been the background of some of the greatest contributions this country has made to the knowledge of natural history; and I stand as a representative of the study of animal life in the Universities. In the beginning our interests were similar, at any rate similarly catholic; we were baptised with the same baptism, for the majority of your Societies are Natural History Societies and the Scottish Chairs were founded and are still known as Chairs of Natural History. And in the beginning (the Chair I formerly occupied in Aberdeen University was founded in 1753, that in Edinburgh which I now occupy in 1767) the outlook from these Chairs was wide and all-inclusive, they surveyed the world of living nature. Their outlook
was reflected in their product, and the chief products of a University are the men and women who leave its walls.

To take but one line of investigation: think of that great band of naturalist travellers and adventurers who left the University of Edinburgh to gather knowledge in the ends of the earth. We cannot doubt that something of the spirit which animated them was born in those class-rooms where knowledge of the plant and animal worlds was laid open to them. In the Dark Continent of Africa there was James Bruce who discovered the sources of the White Nile, Mungo Park and Balfour Baikie who explored the Niger, Sir Andrew Smith who brought back the first sure knowledge of the Limpopo. To the wastes of the Arctic Ocean went William Scoresby, and, after his time, the Franklin expeditions were staffed by Edinburgh naturalists—Sir John Richardson, who finally led the Franklin search expedition of 1847-49, H. D. S. Goodsir who lost his life with Franklin on the expedition of 1845. The most far-seeing naturalist traveller of them all, Charles Darwin, had his baptism of academic natural history from that same Chair, as his grandfather, Erasmus Darwin, a great man also, had before him. And who can tell how much the scientific exploration of the seas owes to Edinburgh students of the old school, Edward Forbes who founded the science of Oceanography, Sir Wyville Thomson who, as organiser and leader of the Challenger Expedition, conducted the greatest scientific voyage ever planned, and contributed more than any single man to our knowledge of the oceans and their inhabitants; Sir John Murray whom I knew in his later years, who carried on the work of the Challenger after Wyville Thomson’s death, and my old friend Dr. W. S. Bruce who organised and led one of the most successful of those Antarctic Expeditions which marked the opening of the present century. These were great men, men of broad outlook and wide sympathies; practically all of them were students of medicine, for that was then the only gate to the biological courses; many of them never reached the stage of gaining a University degree, but all passed through the discipline of the old-fashioned natural history.

And now the tree of the knowledge of natural history has so flourished that many of its great branches, like an Indian banyan tree, have lowered their own supports into the soil, and have become all but independent offshoots. That is as it should be, for progressive evolution is bound up with increase in specialisation; but specialisation of itself is not enough, evolution also implies more perfect unity and co-ordination with each step in specialisation. Division of labour is useless without co-operation. That, the co-ordination of the developing and diverging branches of knowledge, is the problem of the moment. How that affects the Universities I do not mean to discuss here, but I should like to glance at the changes which specialisation has brought about in the outlook of the local natural history societies.

On reading the addresses of past Presidents of this Conference, I notice that grave differences of opinion have been expressed as to the purposes for which your societies were formed. One view (expressed by Mr. John Hopkinson at the Havre meeting in 1914) is that the purpose of local natural history societies is to investigate the Natural History of their locality, and that no other purpose can justify the existence of such a society. If that definition were accepted, how many of the societies scattered throughout the length and breadth of the land would survive the test? Comparatively few; yet the remaining societies fill a useful place in the development of nature knowledge. I lean to a much wider conception of the function of a Natural History Society (such as that propounded by Prof. G. A. Lebour at the Newcastle meeting of 1916).
In the preface of a little work entitled 'A Natural History,' published by Sir Thomas Blount in 1693, is to be found this sentence: 'The deeper insight any Man hath into the Affairs of Nature, the more he discovers of the Accurateness, and Art, that is in the Contexture of Things,' and that might well be taken as the creed of your societies. It signifies two things. It signifies in the first place that, where two or three are gathered together to recount and discuss in a scientific spirit (which is just the spirit of controlled inquiry) the discoveries made by others, insight into the ways of Nature is being stimulated and deepened. That might almost be regarded as an end in itself. It is the justification for the lecture syllabuses and summer excursions of your societies. It has this further justification, that it is spreading the notion of science and scientific method among the people, and until the scientific spirit of co-operation and of undeviating adherence to truth permeates the populace, there can be no hope that science will take its proper place in guiding the affairs of the nations.

By all means expound, and continue the natural history lectures and discussions. That is one of your contributions to the spread of knowledge, and it has been made the more necessary because of the specialisation to which I referred, and which threatens to divide our science into isolated compartments, to make it a Babel of words and ideas, with, in the language of the geneticist, no crossing over value. In Milton's words:

' A jangling noise of words unknown.
Forthwith a hideous gabble rises loud
Among the builders; each to other calls
Not understood.'

And the words are from 'Paradise Lost'!

But there is a second implication in Sir Thomas Blount's phrase. 'The deeper insight any Man hath into the Affairs of Nature' points to the study of Nature herself at first hand, and that is the greater part, the most attractive and at the same time the most elusive target at which a natural history society may aim. It is to this aspect of the activities of your societies, the direct study of nature, and to the change which specialisation has wrought in the opportunity of original amateur observation, that I wish specially to refer.

The Influence of Specialisation upon the Outlook of the Societies.

The stable work which has kept the local societies alive as contributors to knowledge has been the building up of local lists. Sometimes it was an all-round naturalist, sharp of eye, keen in the discrimination of minute differences, overflowing with general interest in the world around him, who ventured, and ventured successfully, to name all kinds of plants and all kinds of animals. That general activity has ceased; the accumulation of knowledge enforced restrictions, and the local naturalist limited his collecting and his identifications to a particular group which came to be his own pet hobby: he became an entomologist, though even there he concentrated his labours particularly upon butterflies and moths, or bees and wasps, or beetles, or he became a conchologist and collected shells, or an ornithologist, or a microscopist, which covers a multitude of subjects. So he made his local collections, and from them his local lists, and the result is that, owing mainly to the painstaking and persistent labours of the naturalists of the societies, we possess a knowledge, second to that of no other country, of the distribution of the major groups of British animals.

But, alas, this safe and comparatively simple outlet for the energy and
enthusiasm of the local naturalist has of recent years become chocked, blocked by time and progress. The very thoroughness of the listing, carried on through many years, has made more and more remote the possibility of discovering some new thing, and since it is discovery which gives the urge and flavour to all scientific investigation, the salt of local-list making has lost much of its savour. Moreover the fact that new species have now become rare discoveries in the faunas of civilised lands has driven the professional systematist to seek his discoveries in finer and more subtle discrimination between related forms, so that where specific identification was once regarded as all-sufficing, now the determination of sub-species and varieties, geographical races and sub-races, is deemed necessary; where Linnaeus, and naturalists for more than a century after him, were satisfied with binomial labels for plants and animals, the modern specialist demands trinomials. It no longer satisfies this demand for minute accuracy to distinguish a Goldcrest from a Firecrest; one must be able to say whether the Goldcrest, this smallest of our birds, is Regulus regulus regulus, a visitor to Britain from the mainland of Europe, or Regulus regulus anglorum, a British-born subject; or whether the crossbill of the winter months is the alien Loxia curvirostra curvirostra or the native Loxia curvirostra scotica.

This growing subtlety of identification, exemplified in another group by the use of the comparative anatomy of the genetalia of insects, has played into the hands of the specialist; it requires time, thorough knowledge, a mass of specialist literature often difficult to obtain; in fact, more than any other development, it has frozen out the amateur of the natural history societies from a province that for ages was particularly his own.

It would be a grievous blow to the usefulness of the societies and to their self-esteem as a corporate part of the organisation of science in this country were it to be felt that their day of co-operation in scientific progress had come to an end. It has not come to an end, of that I am sure, but I think that the direction of effort must be changed to meet the new conditions, and therefore I propose to suggest some lines of natural history investigation along which the societies may readily contribute their quota to the advancement of knowledge.

The Future Outlook of the Natural History Societies.

In the development of scientific work during the present century two notable changes have been taking place. In the first place there is a marked tendency, due to the growing complexity of scientific problems, to forsake the old individualistic form of research—the researcher ploughing his lonely furrow—and to replace isolation by the collaboration of many workers, organised as a team, whose joint labours, carefully planned, converge upon some definite problem. That is the secret of most present-day attacks upon problems of nutrition, of human diseases, of diseases of domestic animals, of the economic exploitation of the fisheries; it was just such organised team work which enabled the Drosophila-zoology of Morgan to create a flood which almost swept zoologists off their feet.

This method of co-operation is no new thing to the members of this conference. At the Newcastle meeting of 1916 Prof. G. A. Lebour laid before you many excellent suggestions for joint work upon geological problems. To-day I am concerned rather with natural history from the zoological point of view. And the second notable change which has been taking place in scientific development points the way along which the societies might well move, with profit to themselves and to science.

During the present century there has been an enormous change in the
objectives of zoological investigation. Almost since zoology began the pendulum has swung between interest in structure and interest in function, and for many years the structural characteristics of animals themselves dominated, I might almost say usurped, the field; first, it was the superficial structures, which determined the classification of a creature; then when the inquiry was pushed a little deeper, the gross structures of the animals, described on their own account and almost irrespective of their function; and lastly the microscope was called in for a final analysis, so that nothing in a structural sense should be lost. These studies moved far beyond the sphere of the natural history societies, but they expressed the zoological spirit of the times. They are useful and important studies; very properly they will continue to have their followers, and I say no more about them, safe in the assurance that 'old soldiers never die,' although it must be confessed that their blood may run very thin.

But the spirit of the times is changing, and now the emphasis has forsaken structure for structure's sake, and is laid upon the animal as a living thing; zoology is stressing its place as a science of life.

**Joint Enterprises in Biological Problems.**

The combination of these two modern tendencies offers a new outlook and a new field for the societies; the combination of organised co-operation or team work directed towards the solution of biological problems. Let me give you an example or two of the sort of scientific work I have in mind.

We know generally how beasts and birds are distributed throughout Great Britain, and we know that man with his cultivation, and industries, and ribbon-building and so on, interferes with the distribution of some of them. We see the differences, perhaps after the lapse of years, but we do not know enough about the numbers of beasts and birds in any area to be able to recognise changes whenever they occur and before they force themselves upon our notice. The only safe basis for estimating changes must be a census. Some creatures are more easily counted, some are more worth counting, than others: there is the grey squirrel, which has spread since its introductions, ultimately from America, an undesirable alien; we should like to know more about its numbers in different parts, to supplement Mr. A. D. Middleton's account, and as a check upon its movements. Even more interesting is our own red squirrel; in some places it seems to be dying out, in other places it continues to flourish, but only when we get counts can we hope to understand such anomalies. Amongst birds, there is the rook, because of its interest to farmers; the owls, because of their value as destroyers of vermin; we do not even know if blackbirds, thrushes, house-sparrows, are increasing or decreasing throughout the land.

Only successive counts can tell. No single man can make such a count; to be really valuable it must be approximately simultaneous. But your natural history societies could make such a census a success, were it organised for them, if each society plotted out its own area amongst its active members. Moreover organisations are at hand for the planning and analyses of such counts, such as the Bureau of Animal Population at Oxford, and the Institute of Ornithology which has already carried out several successful bird counts. But the societies could help almost indefinitely in the expansion of such scientific investigations.

Consider how much we have learned in recent years, about bird migration by organised co-operation in the ringing of birds in this and other countries; about the arrival and movements of migrating birds and many other seasonal happenings by the organised reports sent to the Royal Meteorological
Society and published annually as a Phenological Report; about the migrations of insects in Great Britain by the reports asked for by a Committee of the South-Eastern Union of Scientific Societies, set up for the purpose of collecting and analysing such information. Members of the societies, as individuals, already do good work in all these investigations, but more observers are required and the societies could organise them.

I have been interested in a rather curious bird-count which has become fashionable amongst the Natural History Societies in Canada and the United States of America—a Christmas bird-count. Each Christmas Day a society arranges that groups of its members should make a survey of the birds in definite nearby localities, and a list of every kind of bird and its numbers in each glade, or park, or wherever it may be, is published. I have compared some of these lists year after year, and I feel sure that any such observations, carried out at the same season and in the same localities and repeated for a series of years, are bound to yield results of interest and sometimes of surprising and unsuspected changes. And besides there is the interest imparted to and shared in by the observers themselves.

Joint enterprises, carefully planned, are profitable enterprises scientifically, and while I should have liked to submit to you a list of problems which could best be tackled in this way (and many such problems will occur to anyone familiar with the trend of natural history investigation) I must pass to another line of attack upon biological problems open to you.

**Biological Problems for the Individual.**

It may be that in some of the societies the number of members interested in natural history is too small to permit of joint enterprises, or it may be that some members prefer the independence of the lone hand. I commend to them the biological type of problem. A most striking difference between the collector's method, which predominated for so long, and the biological method, lies in the material of their study. The collector, and on the whole, the list maker, are looking for rarities, their material becomes more scarce the longer they labour, their collecting of rarities reduces still further a stock which may be dwindling, even towards extinction. Such things are undesirable. On the other hand, the student of life requires no rare material, the more common a creature is the better it suits his method, for his object is to learn something of the principles which regulate the lives of animals, and the more abundant his material the greater likelihood is there of the success of his observations. And there is still opportunity even in the most familiar creatures for the gain of new knowledge, if the inquiry be pushed far enough. Often it need not be pushed very far.

Take the common house-sparrow—I can think of nothing more familiar or more easily observed. My experience of house-sparrows is that every full clutch of eggs contains one egg slightly different in shape and coloration from the rest. Is that the first egg to be laid or the last, and does it produce a sparrow different from the others in size or colour or sex? I doubt if anyone knows. Certainly no one knows exactly how long sparrows' eggs take to incubate in different districts, or how long the fledging period lasts under different conditions. Are the young birds fledged and able to fly sooner when food is plentiful or when the air temperature is high, than when food is scarce and the weather is cold? The answer would have a bearing on a fundamental biological problem—the relationship of growth and development to nourishment and warmth. Another point which seems to me to have some interest: do the second and third clutches of a pair of sparrows take exactly the same time to hatch and fledge as the first clutch?
Do the parent sparrows learn anything from their first experience so that times are speeded up, or do the seasons or the monotony that is bred of repetition slow down the speed of development in the later clutches?

That kind of inquiry could be extended almost indefinitely, because it is applicable to all our common birds ; it would answer unsolved questions ; and best of all it would afford an outlet and a training for that inquisitiveness and desire for acquisition of knowledge which lies at the heart of every naturalist. To those of you who still may think that there is little to be learned about British birds (and we may regard them as the most studied of all the components of the fauna) I would commend the reading of a short article on ‘Our Present Knowledge of the Breeding Biology of Birds,’ contributed by the Rev. F. C. R. Jourdain a few years ago to British Birds (vol. 24, 1930, p. 138). It is because of the unfolded possibilities in a nestful of eggs, that I am mainly against the taking of eggs. Every egg taken destroys an opportunity of recording the development of the young, and that is what we wish to learn about, life and its development. The old Latin tag put it neatly: omne vivum ex ovo, ‘every living thing develops from an egg ’—but nothing ever developed from an empty egg-shell.

From another angle of observation the songs of birds afford many opportunities of discovery. I have a correspondent who settled for his own district, in the North of England, the simple question, ‘How long does a skylark sing?’ With a stop-watch and patience to listen to over 500 songs, he found the average length to be just 2·22 minutes. But there are many things to watch for: Mr. Rollin found, for example, that the larks which sang longest all kept together in the same field. No one suggests that larks make a selected chorus, but why do the best singers all keep together?—the suggestion is that perhaps the older birds tend to flock together, and that from age and practice these may be the more efficient singers. We do not know much about such things; every accumulation of observations is of value, provided the observations are carried out on a scientific plan.

The life-histories of birds, or of insects, or of mammals or any other creatures, the influence of the weather and the seasons upon development and upon the plant and animal population of a circumscribed area, the changes wrought upon plant and animal groups by the interference of man, these and many other problems offer themselves as subjects proper for the direct attack of natural history.

Simple Experimental Zoology.

But there is another sort of attack, somewhat less direct and straightforward in its method, which is open to you and which will appeal to those who wish to exercise a little ingenuity in unravelling the ways of animals, the method of experimental zoology. I know it is a common notion that experimental zoology, a fashionable development of our science at the moment, is bound up with elaborate apparatus, elaborate dissections and transplantations of tissue, and so on; but it has its simpler side, and I have the impression that, where simplicity is possible, the less elaborate the interference with an animal may be, the more likely is the reaction to be the natural reaction.

The sort of experiment I have in mind, and any one of you could carry out such an experiment, is such as Charles Darwin’s test for the intelligence of an earthworm. An earthworm has a very tiny brain—that was a real step in the evolution of life upon the earth, for before worms existed there were no brains at all; and Darwin wished to know if that simple brain endowed a worm with any glimmering of intelligence. Worms have a habit of pulling
things into their burrows. Darwin supplied them with triangles of paper which could be pulled in easily by the tip, but with difficulty by the broad base. He found that most of the triangles were pulled in the easy way, and concluding that that involved a decision or a discovery that there was an easy way, he was prepared to allow a modicum of intelligence to the earthworm.

Or let me show you, from an experience of my own, how simply an experiment may develop. Twenty-four years ago I was spending a Saturday afternoon basking in my garden in Edinburgh in October sunshine. I had three papers, which I read at intervals. One was the *Scotsman*; and as I read I noticed that a small cloud of insects, the Winter midge (*Trichocera hiemalis*), a relative of the Crane-flies, kept hovering above the newspaper-sheet at a height of about 4 ft. Ultimately I laid aside the *Scotsman*, and began to read the old green Saturday *Westminster Gazette*. The insect cloud still hovered above, but I was surprised to see that it had descended very markedly. I then tested the insects with *Country Life*, a magazine with highly glazed paper, and the cloud at once rose, and hovered at a greater height than even for the *Scotsman*.

Very little consideration indicated that the height of the cloud of winter midges was regulated in some way by the colour or the light reflected from the surfaces over which they hovered. The next step in the test was a simple one. I prepared several pieces of cardboard all of equal size, and painted them with different colours, black, white, blue, green, orange, red, keeping the tone of the colours as nearly equal as possible. And then I tried them on the winter midges; but to make the decision as easy as possible for them I gave them only two colours to choose between at a time: black and white, and the cloud hovered over the white; I covered the black card with a blue card, and the cloud still remained over the white: then I covered the white with the red, so that they had to choose between blue and red, and the cloud left the red and came within a minute to hover over the blue. And so on for all the colours, until I had worked out the preferences of that hovering cloud: and I came to the conclusion from these simple tests that colours influenced them in the order of their wave-length—the shorter wave-lengths, blue end of the spectrum, were preferred to the longer wave-lengths, red end of the spectrum; indeed, that the insects were simply reacting, not to any colour as a colour, but to intensity of reflected light.

Some of you are familiar with the interesting results that came of Lord Avebury's equally simple experiments with bees and wasps and coloured discs of paper. There is no end to that sort of experiment. I listened a few months ago in Edinburgh to Miss Ilse describe her recent colour-tests with butterflies. The results were extraordinary. Whenever it hatches, a butterfly is attracted to a particular colour, but different kinds of butterflies prefer distinctly different colours. Yet the original preference does not hold a compelling attraction for a butterfly throughout its life, for when it learns by experience the flowers which contain the nectar it desires, the original preference fades before the colours of the nectar-bearing flowers.

There are great possibilities in such simple ways of testing the reactions of living things, and the method is one which lies ready to the hand of the inquiring naturalist. Only I must warn you that experiments have to be planned with care, and their results scrutinised with caution before a wise conclusion may be ventured.

Even so I do not pretend that those lines of observation which I have suggested to you will lead to great discoveries, great discoveries lie in the
lap of the gods; but I do say that the natural history outlook demands from
the observer himself accuracy, persistent or continuous observation, careful
recording, and in the end that rigid consideration which leads from facts
to general truths; that is a training of which the world stands badly in need
to-day, for it leads to uncompromising adherence to the issue of carefully
sifted facts. To the societies themselves the natural history outlook will
bring, is indeed bringing, new vigour, and with it that satisfaction and
honest pride which go with the enlarging, even in modest degree, of the
bounds of knowledge.

Following the President’s address, a communication by Mr. J.
RAMSBOTTOM, O.B.E., on The biological work of Natural History Societies
and its co-ordination, was considered and discussed; and arising there-
from it was resolved:

That the Conference recommend to the Council of the British
Association the desirability of establishing through its Corresponding
Societies Committee a close liaison with the Association for the Study
of Systematics in relation to General Biology with a view to the
Corresponding Societies undertaking work bearing upon systematic
problems.

Monday, September 6.

Prof. F. E. WEISS, F.R.S.—What Dovedale means to the botanist.

The beautiful valley of the Dove was suggested to the National Parks
Committee appointed by the Government as a suitable area for a national
park or nature reserve. This suggestion was supported by competent
scientific opinion and by a large number of administrative authorities, and
the importance of its preservation, both for its scientific amenities and for
the enjoyment of the public, has been very widely recognised. Despite the
inaction of the Government, which has not taken any steps to implement
the recommendations of its Committee, the preservation of Dovedale and of
the adjacent Manifold Valley has in recent years been brought nearer to
realisation by munificent gifts of considerable stretches of land in and around
the area which have been handed over to the National Trust. Fore-
most amongst these benefactors is Sir Robert McDougall, who has purchased
and donated to the public considerable portions along and near the banks
of the Dove as well as extensive areas of the adjacent Manifold Valley.
The Pilgrim Trust has been equally generous and Mr. Hodgson Kerfoot
and the Imperial Chemical Industries have come forward to complete
the acquisition of further stretches of the valley. The London Midland
and Scottish Railway Company have also presented the site of the dismantled
Manifold Valley Light Railway and the Staffordshire County Council
proposes to spend £6,000 on transforming the track into a public path.
If the apathy of the Government could be overcome by public pressure and
the land between Dovedale and the Manifold Valley could be scheduled
for the purpose of establishing a national park, one of the ideals of nature
lovers might be realised by securing for the public in perpetuity one of the
favourite beauty spots of the Midlands and North of England.

Even if the complete scheme for a national park remains as something
to be striven for, all must be grateful for the good beginning that has been made by the generous gifts of these benefactors. The land already acquired for the public includes open meadow land, the river and river banks, as well as woodland and scrub, so that a great variety of plants, birds, insects and other wild life is open to observation and study. I am mainly concerned with the vegetation, and shall deal with the plants found in Dovedale which are typical of a Midland limestone dale.

In early spring, Dovedale will reveal some interesting plants to the botanist. The Mountain Pepperwort (Hutchinsia) will be found in flower among the limestone cliffs, while the rue-leaved Saxifrage adorns the walls. In moist situations both forms of Golden Saxifrage are abundant and later in the year the Mossy Saxifrage and the Meadow Saxifrage are common. The early flowering Green Hellebore is very scarce in Dovedale and the sweet-scented Mezereon is equally rare. In early summer the woodlands are sweet with the scent of Lilies-of-the-Valley and with Woodruff. In shady places the Mountain Currant, rare in Britain, may be found in flower, and in more sunny situations among the screes the white flowers of the Rock Bramble will be seen, to be followed in autumn by its scarlet berries. In similar situations the Lesser Rue, scarce except in limestone districts, is comparatively abundant, and so is the blood-coloured Cranesbill, and in the meadow-land the Birdfoot Trefoil and Lady’s Finger or Kidney Vetch; while in adjacent dales Jacob’s Ladder is to be found. The late summer and autumn bring the Broadleaved Campanula and the Great Mullein, but the Small Teasle is local and rare. The Spindle Tree with its brightly coloured fruits is also very scarce in Dovedale. Of orchids, the early Purple Orchis, the Spotted Orchis and the Butterfly Orchis are common in the meadow-land, while in the shade the Helleborine is not uncommon. These are only some of the plants that we can search for and shall enjoy finding in what has been preserved for us and for posterity in Dovedale by generous donors.

Mr. F. A. Holmes exhibited and described a map of Dovedale and the neighbouring Manifold Valley, indicating the area under the control of the National Trust and calling special attention to further portions of the area which it is earnestly hoped would be secured for safe custody and permanent preservation in its natural state for the benefit of the nation as a National Park.

Capt. C. W. Hume.—The rabbit problem in Britain.

Variation in abundance of the rabbit.—Market statistics suggest that the abundance of the rabbit is characterised by cyclical fluctuations having a period of about seven years, superimposed upon a steady increase. Two theories that have gained wide currency are contradicted by the facts: (i) abundance is not closely correlated with rainfall, and reaches a peak sometimes after dry years and sometimes after wet years; (ii) the recent peak of abundance has not been caused by a diminution of trapping due to a fall in prices, for the numbers trapped have rapidly increased each year since 1932. Presumably disease and predators are major factors in determining the cycle.

If history repeats itself, the rabbit-population is likely to fall temporarily in the near future, rising subsequently till it reaches a new high record in 1943 or 1944 if co-ordinated efforts to control the increase be not made. Variation of abundance with locality appears to be correlated with economic factors.
Economic status of the rabbit.—The wild rabbit causes incalculable losses to agriculture and forestry by destruction of trees, crops and banks, by carrying disease, by souring the ground, and by changing the botanical composition of pastures in an unfavourable manner. Its low nutritive value makes it an expensive form of food; it is frequently infested with tapeworm, coccidiosis and other parasitic diseases; and the flesh has the unwholesome feature that it contains the blood, whence its red colour as compared with that of the domestic or Ostend rabbit.

On the other hand, wild rabbits are a source of profit to furriers, felt-hat manufacturers, trap-manufacturers, game-keepers and professional rabbit-trappers; moreover unsuccessful farmers often prize their rabbits. Prosecutions for poaching wild rabbits are fairly frequent.

It is not difficult to exterminate rabbits when co-ordinated action is taken, but when ground has been cleared it is usually reinfested from neighbouring ground. The fact that rabbits have a market value prevents the general adoption of drastic means such as cyanide fumigation for exterminating them, especially in years of relatively small abundance when prices rise.

Methods of killing wild rabbits.—This subject has been clouded by controversy between persons who object to the gin trap on account of its cruelty, and game-preservers and others who are anxious to defend its use. The facts appear to be as follows. The gin trap is the most profitable means for taking rabbits for the market; as a means for keeping down rabbits it is, however, inefficient. Cyanide fumigation (with Cyanogas, Cymag or Calcid) is the most efficient means for keeping down rabbits, but yields no profit from sales. It kills humanely, and half-gassed animals do not suffer from after-effects. The poisoned rabbits are not harmful if eaten. Being highly poisonous it requires careful handling, but in practice casualties do not occur when it is used in the open air. It is applicable in all cases in which a trap could be set in a hole. The foregoing remarks do not necessarily apply to fumigants other than cyanide fumigants. Other methods such as snaring, long-netting, ferreting and spot-lighting yield heavy catches but are not universally applicable. Pit-traps and smooses are suitable mainly for wired-in warrens. Shooting is restricted by law, and shot rabbits fetch relatively low prices in consequence of damage to the pelts.

Humanitarian aspect and need for scientific inquiry.—The gin trap is inhumane, and it is desirable that the sacrifice, if any, which the community would make in abjuring this instrument should be authoritatively assessed. The Mersey Committee of the House of Lords formulated a compromise between conflicting opinions and interests, and the time at its disposal did not permit of a thorough investigation into matters of fact. There is need for an experimental and quantitative investigation into the relative merits and ecological effects of the principal methods of dealing with mammals that are harmful to agriculture.

Arising out of Captain Hume's communication and the discussion which followed, the delegates passed the following resolution:

That the Council of the British Association be requested to represent to His Majesty's Minister of Agriculture and to His Majesty's Secretary of State for Scotland the necessity of instituting an enquiry to ascertain the effects, in respect of efficiency, economic reactions, and humaneness, of available methods of dealing with rodents and other wild mammals that affect agriculture.
From earliest times men must have found considerable difficulty in the food supply when living in large communities. As man has become more civilised, and his life has become more organised, he has made mistakes in dietetics—mistakes which a committee of the League of Nations has investigated and now reported upon.

There is now a ‘newer knowledge’ of nutrition which will guide us in the selection of our food—for the quality of our food is perhaps of greater consequence to us than is the quantity.

To the chemist Lavoisier belongs the credit of having first approached human nutrition from the fundamental scientific aspect. His discovery that the animal body is essentially a kind of furnace, in which the food digested undergoes slow combustion and is ultimately converted into heat, remains the chief corner-stone of the modern science of dietetics.

Foods may be roughly classified into ‘body workers and warmers’ (essentially carbohydrates and fats), ‘body builders’ (essentially protein), and ‘body protectors’ (essentially vitamins and minerals). The first are required to maintain the body temperature above that of the surrounding air, to supply the body with energy for carrying on the internal operations of digestion, etc., and for doing external work.

Proteins are needed for building up cellular tissues, both in growth and in repair; and the newer work on nutrition has demonstrated not only the superiority of certain proteins for body building, but also something of the role of vitamins and minerals for the efficient functioning of individual organs, and for co-ordinating their activities.

A food is evaluated as a supplier of energy by measuring the heat it gives out when it is oxidised in the body. The chief suppliers of energy are the carbohydrates (sugars and starch) and fats, though the proteins also contribute their quota. The total energy value of human food is usually measured in terms of calories, but for foods given to useful domesticated animals like cows, sheep and pigs, a larger unit is employed—that of 1 lb. of starch. The starch value, or ‘starch equivalent’ of a food is a number expressing how much of it acts as starch during digestion.

Thus the S.E. of linseed cake is 72, i.e. 100 parts by weight of it supply the same amount of energy as 72 parts of starch. One pound of starch is equivalent to 1,861 calories. A similar unit is used for proteins. The ‘protein equivalent’ of a food expresses the percentage of the food which plays the same part in the animal economy as pure digestible protein. Thus linseed cake has a protein equivalent of 24, i.e. 100 parts of linseed cake are equal in body-building value to 24 parts of pure digestible protein.
The crude protein of a food is the percentage of nitrogen multiplied by 6·25. The percentage of crude protein in linseed cake is 29.

The quantitative food requirements of farm animals have been studied far more intensively and accurately than have those of human beings. The amounts of starch equivalent and protein required by domesticated animals at different periods of their life, and for different requirements, have been determined practically, so that it is now a matter of routine to provide them with a 'balance ration' that contains all the necessary amounts of carbohydrate, protein, etc., and in the correct proportions, not only for 'maintenance', i.e. for keeping the body supplied with energy, but also for 'production', i.e. for enabling it to produce the needed amounts of marketable produce, milk, meat or eggs.

As an illustration: a milch cow weighing 1,000 lb. requires daily 6 lb. of starch equivalent, and 0·6 lb. of protein equivalent, to maintain it in health and keep its weight constant. For each gallon of milk (3·7 per cent. fat) it produces, it will require 2·5 lb. starch equivalent, including 0·6 lb. digestible protein. Hence a cow weighing 1,000 lb. and giving 4 gallons of milk a day will need:

<table>
<thead>
<tr>
<th>Starch Equiv.</th>
<th>Protein Equiv.</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb.</td>
<td>lb.</td>
</tr>
<tr>
<td>For maintenance</td>
<td>6·0</td>
</tr>
<tr>
<td>For producing 4 gal. milk</td>
<td>10·0</td>
</tr>
<tr>
<td>Total to be fed per day</td>
<td>16·0</td>
</tr>
</tbody>
</table>

These amounts can be made up in a variety of ways, the starch equivalent can be supplied as grass, hay, straw, oats, barley, maize, roots, etc., and the protein as oil-cake or good grass; but it is essential to keep the ration 'balanced' in respect of S.E. and P.E. to avoid waste and to maintain health; and also to see that its bulk does not exceed the appetite of the animal.

Besides this, the animal must receive sufficient minerals and vitamins to maintain health.

### Some Typical Food Requirements.

<table>
<thead>
<tr>
<th>Starch Equiv.</th>
<th>Protein Equiv.</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb.</td>
<td>lb.</td>
</tr>
<tr>
<td>To feed a milch cow for 1 year and produce 800 gall. milk</td>
<td>4,200</td>
</tr>
<tr>
<td>To feed a heifer calf from 2 months (150 lb.) to 3 years (11 cwt.) when it produces its first calf</td>
<td>7,300</td>
</tr>
<tr>
<td>To feed a calf until it is a 2-year-old bullock weighing 10 cwt.</td>
<td>5,000</td>
</tr>
<tr>
<td>To feed a young pig from 50 lb. to 160 lb. (bacon weight)</td>
<td>330</td>
</tr>
<tr>
<td>To feed a young sheep (teg) from 80 to 180 lb.</td>
<td>510</td>
</tr>
<tr>
<td>To feed a hen for 1 year—produce 160 eggs</td>
<td>60</td>
</tr>
<tr>
<td>To feed a man for 1 year doing hard work</td>
<td>640</td>
</tr>
<tr>
<td>To feed a man for 1 year doing little work</td>
<td>530</td>
</tr>
<tr>
<td>To feed a boy of 10 years growing and energetic</td>
<td>450</td>
</tr>
</tbody>
</table>
In the case of man, half the protein should be first-class protein, i.e. it should be derived from meat and milk.

In the case of animals, some recent work at the Hannah Dairy Research Institute indicates that the protein contained in grass is of greater value than the protein obtained from the seeds of plants.

We will now consider the source of our food supply—how it comes from the plant, and the animal through the plant.

The original source of all human and animal energy is solar radiation. Although plants take up some of their food (water, nitrogen and minerals) through their roots, part of it is derived from the carbon dioxide in the air, which, under the influence of sunlight, is decomposed by the green colouring matter in the leaves, the carbon being assimilated and the oxygen returned to the air. The compounds produced, carbohydrates and proteins, have the highest chemical energy in the life-cycle of the plant. The building up of the leaf is a storing up of chemical energy, and all the other processes involved in a plant’s life, including ripening to form seed, and the sprouting of the new seed to form another plant, are but stages in the degradation of that energy. The energy of all parasites on the plant is also derived from the energy in the leaf, and the whole activity of the animal world comes from this source. In other words, the animal world is but an incident in the decay of leaf matter.

The leaf of a plant may contain 50 per cent. to 90 per cent. water, but the dry matter consists largely of soluble carbohydrates and proteins, together with minerals and vitamins. When the plant begins to ripen, the carbohydrates change into cellulose, and protein moves from the leaf into the flower and seed.

In the case of cereals and grasses—and probably of most other plants—there is little further synthesis after the plant starts to ripen. All the feeding value is present in a crop of grass—say at the end of May—and though we leave the grass until the latter end of June before we cut it for hay, the feeding value of the crop does not increase during that time. (The reason we do not cut it for hay at the end of May is that in this stage of growth it is so difficult to get the grass killed by the sun, so that there would be grave danger of the stack taking fire spontaneously, and in any case there would be considerable losses due to fermentation in the stack.)

It will be useful at this stage to consider what are the chief foods men eat, and from whence they come.

We obtain the best quality protein from meat, milk, cheese and fish. In these foods, the protein which originally existed in the leaf of the plant (or a plankton in the sea) has been selected during metabolism by the animal for its own purpose—since man is similarly constituted to the animals, this selection is useful to us—and we can call these first-class protein foods. Fruit and grain of various kinds also contain protein, but in this case the protein from the leaf has been selected by the plant which has taken to the seed those proteins necessary for plant regeneration. From the point of view of the animal, the plant is not a particularly good selector of proteins and we class these as second-class proteins.

Man also eats leaves to some extent, especially spinach, cabbage and lettuce, and these leaves are quite high in protein. In this case there has been no selection of the leaf proteins by animal or plant, and it is probable that this leaf protein is intermediate in value to man between animal and other vegetable protein.

Man obtains starch equivalent to supply heat energy, in the form of bread, cereals, butter, fat and fruit, as well as, to a lesser extent, in meat, milk, cheese, etc.
He obtains protective foods—vitamins and minerals—in small quantities from almost all the foods he eats. But of all foods, leaves are the form of food which contain most, if not all, of the vitamins, and leaves are rich in minerals; though the actual concentration of certain vitamins is greater in some kinds of meat, such as liver, or in certain parts of the grain.

The following diagram shows the derivation of the principal types of human food from leaf matter:

```
LEAF MATTER
  /       \
FRUIT     GRAIN
     |       |
     |       |
MEAT     MILK
         \
       ANIMALS
```

**Fig. I.**

Farm animals—cattle, sheep and pigs—eat grass in the leafy stage, and hay, cereals and feeding cakes. The latter are tropical seeds and nuts from which the oils have been extracted for making soap or margarine.

There is not much doubt that for cattle and sheep grass is the best food when it is available—but the pig thrives best on grain as well, since he has not a stomach large enough to deal with all his food in a bulky fibrous form.

Our system of feeding a farm animal may be illustrated by reference to a milch cow. From early May it grazes the pastures, eating the leaves of grasses and clovers, from which it can obtain all the nourishment it requires, even when it is producing up to 4 gallons of milk a day. Later, in the summer, when the grass has become more stemmy with less leaf, a heavy milking cow finds it more difficult to obtain all the food it requires, especially if the soil is becoming dry and new leaves of grass are not growing. It is then usual to supplement the grass grazed by the cow with a ration of feeding cakes.

From the autumn rains there is generally another flush of leafy grass, and again the heavy yielding cow can obtain nearly all it requires from the pasture. Then, in the late autumn, the cow is usually housed for the winter and fed on hay, roots and feeding cakes, cereals and other meals, until spring returns.

Actually the cow which is giving milk is only fed entirely on grass for quite a short time of the year—perhaps May, part of June, and then again from the middle of August to the middle of September.
Since the war we have learned a good deal about the management of grassland, and, as I hope to show you, we can now get very much more food for our cattle from an acre of land than was previously possible.

Grass grows mostly during the summer, but the rate of growth is not at all even during the warmer part of the year. If left to itself, grass grows during the spring and then ripens. Most grasses flower during June and July, and the seed falls during July and August. If the grass is cut or grazed before it ripens or flowers, it will grow again in an endeavour to flower. Even if it is left uncut, some grasses will start growing again in

**THE FOOD OF A COW**

![Bar Chart](chart.png)

The autumn if light can get through the matt of dead grass to the young shoots. But these conditions do not apply to a well-managed pasture which is kept grazed and prevented from flowering, though they do apply to the overgrown grass found on rough grazings.

In discussing the yield of food given by crops I shall not consider the total weight of the crop but the crude protein content. This is the weight of nitrogen in the crop (found by analysis) multiplied by a factor (6.25), since this is the ratio of nitrogen to total weight in a protein. In grass the crude protein content is usually about 50 per cent. higher than the protein equivalent. In some foods the difference is less.
I use the protein value of the food rather than the starch equivalent because it is in regard to the protein value that there is the greatest danger of the animal receiving insufficient.

Recent investigations of Dr. M'Gonigle and others have shown that the poorer population of this country, though they receive sufficient starch equivalent, are definitely suffering from partial protein starvation. This is especially deleterious for growing children and for expectant and nursing mothers.

As an example of the way in which the growth of grass varies at different times of the year, I can show you the results of an experiment at Reaseheath in Cheshire in 1934, when the grass was cut whenever it was 4 to 5 inches long.

The limitation of productivity was chiefly water supply as it was a year of drought.

During 1935 there was more rain and the increase of yield due to fertilising was greater.

These two tables indicate the different growth in two succeeding years, and the difference of the distribution of that growth over the season.
It is obvious that during some of the summer months there is plenty of grass, and at other times a shortage.

It is usual to keep as many cattle and sheep on a farm as can eat the grass during the leaner months of the summer.

In Jersey and Denmark cattle are tethered on the pastures; when they have grazed the grass around them they are moved off to another spot, and

Yield of Crude Protein in Grass from cutting during the summer months.

1935

Fertilised  Unfertilised
(2½ cwt Am\(\text{SO}_4\) per acre)

<table>
<thead>
<tr>
<th>Month</th>
<th>1935 Fertilised</th>
<th>1935 Unfertilised</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>2.94</td>
<td>2.29</td>
</tr>
<tr>
<td>June</td>
<td>0.89</td>
<td>0.57</td>
</tr>
<tr>
<td>July</td>
<td>1.98</td>
<td>0.83</td>
</tr>
<tr>
<td>Aug</td>
<td>0.97</td>
<td>0.46</td>
</tr>
<tr>
<td>Sept</td>
<td>0.95</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Fig. 4.

the pasture is treated with liquid manure. The grass grows again rapidly, and is regrazed when it is 3 or 4 inches high. By this means it is possible to control the grazing, so that the grass never becomes too long and coarse, or matures to seed.

A more elaborate and more scientific method of controlled grazing was initiated by Prof. Falcke, of Leipzig University, in 1904, in which he used sulphate of ammonia in place of liquid manure. In 1916, Prof. H. Warnbold developed this method in extensive trials at Hohenheim, and about ten years later Mr. T. H. J. Carroll and Sir Frederick Keeble introduced it into England under the name of 'New System of Grassland Management.' In essence, the system consists in dividing a field into six or eight small paddocks, treating the grass with sulphate of ammonia at intervals of a few
weeks, and grazing, by milch cows and other stock, as soon as the grass attains a height of 4-5 inches, leaving 'followers' (dry cows and cows in calf) to clear up the remains. When the cows come off the pasture, it is harrowed to spread the dung, and then treated again with sulphate of ammonia. This 'new system' was started on the farm of Mr. Brunton at Marton, near Middlesbrough, and has been successfully worked there for ten years; under it, the number of cows carried by an acre of grassland during the summer has been doubled.

Although the 'new system' never became general, the experimental work done with it left a valuable aftermath, notably the extension of the grazing season in the spring and in the autumn. By suitable management of grazing, and applying a moderate dressing of nitrogen in February or March, sufficient growth can as a rule be obtained to feed cattle on pasture two or three weeks earlier than usual, thus saving the farmer the cost of feeding concentrates during that period.

Until about ten years ago our farmers never contemplated the use of nitrogenous fertilisers on pastures: they would kill the clovers, and especially wild white clover, which is the chief permanent nitrogen-fixing legume in a pasture. Mr. Brunton, however, found that the 'new system' did not involve the destruction of clovers.

About eight years ago Sir Frederick Keeble and Lt.-Col. W. R. Peel decided to start experiments upon the effect of fertilisers and of management on the composition of a pasture, and this work was placed under the direction of Mr. Martin Jones, who had been working with Prof. R. G. Stapledon at Aberystwyth.

Mr. Martin Jones demonstrated that the bad effects of nitrogenous fertilisers were due to insufficient grazing, and grazing at the wrong time, which allowed the coarser grasses to grow long and choke the finer grasses and clovers.

I think I can best illustrate the result of Martin Jones' work by reference to Fig. 5, on which are shown the times of the year at which some grasses grow leaf. A pasture is made up of many grasses, but the consideration of these few grasses will, I hope, be enough to make the principle clear.

Nardus only grows leaf in July, and rapidly becomes fibrous and unpalatable. It is therefore considered a weed.

Bent is better. It grows leaf for a period of three months.

Indigenous Perennial Rye Grass grows leaf during six months of the year if—

(i) it has already a well-established and developed root system;
(ii) the supply of water in the soil is sufficient for growth;
(iii) the necessary nitrogen and minerals are present in the soil in a suitable form.

If the pasture is grazed in early April when perennial rye grass has only made little growth, and cocksfoot has made no growth at all, then the perennial rye grass receives a check, for stock will eat its young palatable shoots to ground level since there is no other green growth available. If, after grazing, the field is rested, cocksfoot, which is now starting to grow, has no perennial rye grass to compete with and no grazing animals to check its growth: it passes through its critical period under favourable conditions. It becomes strong, and successfully competes with the perennial rye grass which is now endeavouring to make its second growth. If, on the other hand, the field is rested in April when perennial rye grass is starting to grow, and grazed a fortnight later when cocksfoot starts, the cocksfoot will
be more punished than the perennial rye grass, for the latter has grown and developed its root system.

Hard grazing at the end of May, when wild white clover starts its growth, reduced the competition of the tall growing grasses—perennial rye grass and cocksfoot. The wild white clover, freed from the overshadowing effect of these grasses, develops. If the field is shut up for hay, in the early spring the tall grasses develop and overshadow the wild white clover, with the result that the clover population is greatly reduced and may be eliminated after successive years of this treatment. By hard grazing in

Periods of Productive Growth
of Leaf of some Grasses.

<table>
<thead>
<tr>
<th>Nardus</th>
<th>Bent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild White Clover</td>
<td>Rough Stalked Meadow Grass</td>
</tr>
<tr>
<td>Cocksfoot</td>
<td>Perennial Rye Grass</td>
</tr>
</tbody>
</table>

Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

Fig. 5.

early summer in subsequent years, the clover can be brought back, the rate of progress being increased if the pasture is kept hard grazed both winter and summer.

There is another important point in pasture management which I can illustrate from the diagram. The earliest grass which we can grow in the spring is perennial rye grass. It will usually grow quite early in April if there is a well-established root system. From the diagram we see that perennial rye grass grows as late as September and October, so if we do not graze or cut the pasture during the latter half of September and early October, perennial rye grass will grow and establish a strong root system. After October, when the grass has ceased to grow, we can eat off the grass without damaging the root system, but if we want early grass next year we must take the cattle off about Christmas and fertilise the pasture with
ammonium sulphate or nitro chalk in early spring. Of course, we must have sufficient lime, phosphate and potash present.

By the proper management of the grassland on an English farm, it is now possible to provide good grazing from the middle of April to almost the end of October, and this management will be made easier, and the period extended, when we use indigenous strains of grasses such as have been bred by Prof. Stapledon and his co-workers at Aberystwyth.

Besides good grassland management, let us for the moment consider the effects of bad grassland management.

If we graze a pasture hard in the spring every year, we check the perennial rye grass and cocksfoot, and then if we undergraze from the end of May the grass will grow in tufts which will become chiefly Yorkshire fog and bent. Other parts of the field will be kept grazed short and will consist largely of wild white clover, because the animal, offered far more than it can eat, makes a selection.

If a field is cut for hay, the wild white clover will be checked, and if this is done year after year, clover will be almost entirely eliminated. Taking a crop of hay from a permanent pasture will always be a severe check to the growth of wild white clover, just as close grazing at the end of May and for the rest of the summer will tend to increase the wild white clover at the expense of everything else.

There are many other ways in which we can ill-treat a permanent pasture.

Good grassland management consists in keeping a balance amongst the desired grasses and clovers by not ill-treating any one constituent of the pasture too long, and by alternating the treatment of the pasture each year so that desirable grasses which are discouraged one year are encouraged the next, and those which have been encouraged must be checked in the following year lest they become too strong.

The good management of grassland is not achieved by blindly following a rotation, but by observing the results of past treatment and following the principles based on the work of Stapledon and Martin Jones.

By good grassland management a large amount of food can be grown on an acre of land, as we shall see later, but this grass must be grazed off or cut to suit the grass and clover population of the field, and not to suit the immediate demands of the animals alone, so that if we are going to have properly managed grassland we must consider how we can manage our farms. There are the following alternatives:

1. A small part of the grassland on a farm is well managed and the rest takes its chance. The well-managed part is cut or grazed at the right time, and the rest of the grassland becomes a rough grazing. This has been done on some farms, where the farmer has more or less managed his fields near the farm and has let the rest become rough grazings.

2. The whole of the grassland might be well managed—but when a field required grazing and there were no animals to graze it, the field would be mown and the grass wasted—except at a time suitable for making hay. This system works, but it is wasteful and difficult to carry out, and the land must be understocked.

3. The whole of the grassland on the farm may be managed well, and surplus grass cut and preserved for the winter feed. In this case it is worth while growing as much grass as possible, and nitrogenous fertilisers will be found to assist the system of management. The quantities of food produced per acre, on this system, are obviously much greater than on the other two systems.
Grass Preservation.

Hay.—Excess grass in a mature stage during June and July can be made into hay. The grass is cut and dried in the sun. When killed and dry, it is made into a stack, where it ferments—more or less. If rain has fallen on the hay it will have lost some of its feeding value. In general the losses during haymaking and maturing in the stack are about 40 per cent.

Protein Values calculated on Dry Matter.

<table>
<thead>
<tr>
<th></th>
<th>Crude Protein</th>
<th>P.E.</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay</td>
<td>9</td>
<td>3.6</td>
<td>35</td>
</tr>
<tr>
<td>Young Grass</td>
<td>17</td>
<td>12</td>
<td>56</td>
</tr>
<tr>
<td>Young Grass Silage</td>
<td>15</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Linseed Cake</td>
<td>29</td>
<td>24</td>
<td>72</td>
</tr>
<tr>
<td>Dried Grass</td>
<td>17</td>
<td>12</td>
<td>56</td>
</tr>
<tr>
<td>Plam Kernal Cake</td>
<td>19</td>
<td>17</td>
<td>73</td>
</tr>
</tbody>
</table>

Production of Grass, 1935
(cwt of Crude Protein per acre)

FIG. 6.
Grass Silage.—The practice of ensilage was introduced into Britain in the 1840's, but did not get under way until the 'eighties. Since then it has increased, but only to a moderate extent, although it is much used in other countries—notably in New Zealand and Germany.

Dr. S. J. Watson, of Jealott's Hill, has recently investigated the merits of different methods of making silage. He has found that grass, whether young and leafy or mature, may be made into silage. In order to prevent excessive bacterial decomposition of young high protein grass in the silo, it is necessary to keep the grass acid. This is done either by the addition of hydrochloric and sulphuric acids, or, I believe better, by adding molasses to the grass. The sugar of the molasses is fermented to lactic acid, which is effective in keeping the mass acid.

Grass Drying.—When Dr. Woodman discovered, or rediscovered, the high protein content of young grass, he suggested its preservation by artificial drying, and Prof. Wood got into touch with Sir Frederick Keeble, who asked us at Billingham to dry some young grass. In 1927 we dried the cuttings of cricket fields and made about five tons of dried grass for experiments at Cambridge on feeding animals.

Young grass containing perhaps 75 per cent. or 80 per cent. of water can be dried to about 3 per cent. water by blowing a stream of hot air through the grass.

The dried grass is practically identical in feeding value with the original grass. It is green, and contains the minerals and vitamins unchanged.

As an example of the method of grass drying I will describe the Tednambury Drier.
This consists essentially of a furnace to burn coke, a fan, and the drier proper. The fan draws air through the coke bed in the furnace, and this mixes with secondary air so as to produce air at about 125° C. The fan blows this under the perforated tray on which the grass is laid about 2 ft. thick. The tray is about 10 ft. square.

In order to prevent the air from blowing holes in the bed of grass, hurdles are laid on top of the bed. When the grass is partially dry, and has shrunk,

**Production of Grass. 1936.**
*(cwt. of Crude Protein per acre)*

![Graph showing production of grass](image)

the hurdles are removed and more grass is added. Drying then proceeds again. When the grass is becoming dry in patches on top, the fan is stopped and the grass on the tray is tedded to mix it up well. The hurdles are put back, and the grass is finally dried by blowing more air through it.

The dried grass is preferably baled, but it can be stored in stacks or bins.

**Application of Grass Drying to a Farm.**—Nearly four years ago, when we had at last got a pretty reliable drier which would produce grass at an economic cost, Colonel Peel undertook to run Dairy House Farm, near Middlewich, on a system including the preservation of summer grass by
drying and silage, and this has now been done for three complete years. What has been done on the farm is shown in Figs. 6, 7, 8 and 9, which show the amount of crude protein produced each month in various forms—grazing, hay, dried grass and silage—and the amount of crude protein consumed each month by the stock. These values have been found to be of more interest than the weight of food produced and consumed.

The amount of food obtained from a field by grazing has been calculated back from the results achieved by the animal. Thus if a 1,000 lb. cow had been maintained for one day, and had yielded four gallons of milk, we should conclude that the grass consumed had contained 16 lb. of starch equivalent, and 3 lb. of protein equivalent, or 4.5 lb. of crude protein. The cow must have had at least this quantity, and if it ate more the excess must have been wasted.

The foods not derived from grass consisted of roots, cereals and feeding cakes.

In 1935 the average yield of crude protein per acre over the whole farm was 595 lb. and in 1936—which was a wetter year—was 680 lb., but as we get more experience in managing the grassland we are learning each year how to produce more food per acre.

Let us compare the yields of protein and starch equivalent obtained by various treatments from one acre of land.
Food obtained from an Acre of Grassland under Various Treatments.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crude Protein (lb.)</th>
<th>Starch Equivalent (lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Four cuts (1934)</td>
<td>1,400</td>
<td>5,600</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>561</td>
</tr>
<tr>
<td>2. A field at Dairy House twice cut and then grazed</td>
<td>914</td>
<td>3,400</td>
</tr>
<tr>
<td>3. A field at Dairy House mown for hay and aftermath grazed</td>
<td>585</td>
<td>2,000</td>
</tr>
<tr>
<td>4. Intensive grazing at Mr. Brunton’s farm (average of 10 years)</td>
<td>681</td>
<td>2,900</td>
</tr>
<tr>
<td>5. Ordinary pasture (calculated from Sir Thos. Middleton’s data)</td>
<td>180</td>
<td>760</td>
</tr>
<tr>
<td>6. Ordinary meadow (calculated from Sir Thos. Middleton’s data)</td>
<td>200</td>
<td>840</td>
</tr>
<tr>
<td>7. Dairy House (average of whole farm, 1935)</td>
<td>595</td>
<td>2,280</td>
</tr>
<tr>
<td>8. &quot; (17.7 cwt.) &quot; &quot; &quot; &quot; 1936</td>
<td>680</td>
<td>2,780</td>
</tr>
<tr>
<td>9. Wheat</td>
<td>178</td>
<td>1,400</td>
</tr>
</tbody>
</table>

At Dairy House we are probably producing three to four times as much food (for animals) per acre as is being produced on the average grass farm in this country. At the same time we are doing the animals well—the cows have a good bloom on their coats even at the end of the winter, and the young stock thrive well. The introduction of drying on the farm has not only produced the winter feed for the cattle, but it has enabled the grassland to be improved, so that the grazing period is extended earlier in the spring and later into the autumn. It is also probable that the cows yield more milk during the winter than they would do on other rations. At Dairy House last year, when the cows went out to grass in the spring, the increased yield of milk was 9.6 per cent., whilst at another farm, equally well managed but where dried grass was not fed, the increase in yield was 17.6 per cent. From this one may conclude that during the latter part of the winter the cows at Dairy House were giving about 8 per cent. more milk than they would have done on ordinary feeding-stuffs. This is perhaps to be expected, for grass is the natural food of cows, and the protein of grass probably contains a better assortment of amino-acids for milk production than do the proteins of feeding cakes, and we know that dried grass provides the vitamins and minerals required.

By the use of a grass drier we have increased the food production on the farm so that we do not require to buy concentrated feeding-stuffs so long as we keep only the same number of animals as were formerly kept on the farm, but to cows giving more than four gallons of milk per day we give an extra ration of a high protein food such as linseed cake.

There is no reason why more cows should not be kept, and feeding cakes fed as well as dried grass, except that we have no more cow houses on the farm. The solution of this problem in the warmer parts of England is perhaps the use of the Hoziere Bale system in which the cows are kept and milked in the field all the year round. If the number of cows in the country were generally increased we should have to make more cheese or butter than we do now, or, of course, we might drink more milk. To bring our consumption of milk up to the level recommended by the League of Nations Commission on Nutrition, it has been estimated by Sir John Orr that we should need to possess quite another million cows, i.e. increase the present number by nearly 50 per cent.
THE PRODUCTION OF FOOD FOR MAN.

We have considered how much crude protein we can produce from an acre of grassland. In the western part of England in fields laid down with Prof. Stapledon's indigenous pedigree strains of grasses, I believe we should eventually be able to produce 15 cwts. of crude protein per acre, and I hope that some day we may be able to obtain this figure as the average production per acre over a whole farm, but for the present we will be satisfied with a figure of 700 lb. per acre, which we are now obtaining in Cheshire. We will consider how much food for man can be produced from this protein.

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\begin{align*}
1 \text{ acre grass yields} & : \quad 700 \text{ lb. crude protein} \\
\text{giving in the form of dressed beef} & : \quad 45 \text{ lb. of protein} \\
or in the form of milk & : \quad 103 \text{ lb. of protein (300 gallons of milk).} \\
1 \text{ acre of wheat (17.7 cwts.) yields} & : \quad 178 \text{ lb. crude protein} \\
giving in the form of flour & : \quad 100 \text{ lb. of protein.}
\end{align*}
\]

This 700 lb. of crude protein in grass can be fed to produce beef and will yield 45 lb. of protein in the form of dressed joints of beef, or it can be fed to milch cows, when it will yield 103 lb. of protein in the form of milk, which can be drunk or made into cheese.

Let us compare this with the yield of human food obtained from wheat. The average crop of wheat in this country is 17.7 cwts. per acre, containing 178 lb. of crude protein. This wheat can be ground to give flour, bran and wheatings. The flour will contain 100 lb. of protein, which is food for man, and the bran and wheatings 78 lb. of protein for animal feed.

So that an acre of grassland at Dairy House in Cheshire is giving approximately the same amount of food for man in the form of milk as can be obtained from an acre of wheat. But the protein in milk is of more value for human food than the protein in flour. The League of Nations Committee on Nutrition considered that half the protein consumed by man should be of animal origin. Besides this, milk contains vitamins necessary for life, and there is no doubt that in time of necessity we should be in a strong position if our system of agriculture made it possible to produce large quantities of milk protein per acre.

Our national agricultural policy has in the past been based upon wheat as the most important food for man which can be produced in this country. I think we have now demonstrated that more valuable food can be obtained from an acre of land by growing grass and feeding cattle if a grass drier is used.

THE FUTURE.

I have mentioned the possibilities opened up by Prof. Stapledon's strains of grasses of some day producing 1,500 lb. of crude protein per acre. At present we are producing on one or two farms about 700 lb. per acre, but from this we are only able to make 100 lb. of first-class protein in the form of milk, or 45 lb. in the form of beef. If we could feed grass protein to pigs, we might produce 70 lb. of protein in the form of pork, for the pig is a more efficient feeder than the bullock, but grass contains too much fibre to be the principal food for pigs.

Now, from ancient times until the middle ages, animals were well fed in the summer and starved on hay in the winter. There was very little milk available in the winter, and no fat beef. The cows did well to live until the young grass began to grow in the spring. The chief protein food
of man in winter was salted meat and cheese made from summer milk. It is easy to imagine how man discovered the making of cheese. If he tried to keep milk, it went sour and acid, and precipitated the protein. Later, he found better methods of precipitating the protein.

The preparation of a protein food from grass is not so simple, but I believe that it would be possible for our bio-chemists to produce a protein-rich food from grass, containing practically no fibre, but much of the useful foodstuffs present in the grass. We will call it Grass Cheese. From an acre of grassland we can get 700 lb. of protein. Surely we should be able to get grass cheese containing 350 to 600 lb. of crude protein, or 220 to 400 lb. of protein equivalent, as well as carbohydrates. This grass cheese would make a very useful food for pigs—to replace imported feeding-stuffs—and in time of necessity it might supply a maintenance ration for the people.

Let us assume that we can make a grass cheese suitable for man, and that we can obtain 350 lb. of protein equivalent from an acre of grassland. We have seen that a man requires 60 to 95 lb. of protein per annum. We shall be on the safe side if we allow 80 lb. per head of the population, including men, women and children. This quantity will allow for a certain amount of waste.

Then one acre of good grassland would support 4.4 head of people.

Now the land of England and Wales consists of:

- 9.0 million acres of arable land
- 15.7 " " of permanent grass
- 5.4 " " of rough grazings.

To support 40 million people on grass cheese we should require 9.1 million acres of grassland, or just about the whole of our arable acreage.

If we could produce a grass cheese we might put all our arable land under temporary grass, and obtain from it enough food for the nation without slaughtering our cattle. Our milk and beef would be available as extras, and would ensure a sufficiency of food and of vitamins.

If we could make grass cheese and feed men on the leaf protein of grass, we could produce four or five times as much food per acre as we do by growing wheat; and in time of national emergency, instead of ploughing up old pastures and sowing wheat, we should sow down arable land to grass or other leaf crop.

I wish to emphasise the economy and efficiency to be obtained by feeding man on the leaf instead of on the fruit or grain. In the past, grass has been the most important leaf crop for feeding animals, and I see no reason why it should not remain so, as the cultivation of grass is economical of labour; but on the other hand there is no reason why other crops should not be grown to produce large quantities of leaf matter suitable for food. In the form of leaf matter we could grow sufficient food in this country to support the entire population. The problem to be solved is the preparation of the food.
DISCUSSION ON

PHYSIOLOGY AS A SUBJECT OF GENERAL EDUCATION.

(Prof. Winifred Cullis, C.B.E., Dr. H. E. Magee, Prof. R. C. Garry, Dr. L. P. Lockhart.)

DISCUSSION BY SECTION I (PHYSIOLOGY) ON TUESDAY,
SEPTEMBER 7, 1937.

Prof. Winifred Cullis, C.B.E.—Knowledge of the body's working, the basis of healthy living.

To be really in touch with life as it is lived to-day, it is essential to have some knowledge of the basic facts of science. Our living conditions are governed and conditioned by the application of scientific knowledge. In our homes in their heating, lighting, refrigeration, in our transport, in our industries and even in our entertainment (not always to its advantage) mechanisation has become more and more predominant. For many years now as regards certain of the sciences, more particularly physics and chemistry, the need for instruction has been recognised. In this recognition the British Association has played an important part. But the biological sciences did not so early secure a place, except that for some (to me) quite inexplicable reason systematic botany (not the botany of to-day) was regarded as quite 'nice' and as suitable therefore for girls. At present, thanks to a vigorous campaign carried out by many individuals and organisations, we are in the full tide of the establishment of these sciences in the school curriculum. The fullness of this latter makes very understandable the resistance by authority to the admission of any new subjects. A tin, after all, can only contain a certain number of biscuits, and to put in a fresh sort must means mean either the turning out or the limitation of some of the sorts already there. So with the hours available for school work. Naturally, every specialist teacher 'knows' that his own subject is the most valuable from the educational standpoint. We, therefore, who specialise in biological subjects know (and of course we also know how right we are!) how important it is for everyone to have some knowledge of the basic laws and facts as they apply to this business of living. After all to be successfully alive is the fundamental necessity for everything we do, and the more 'alive' we are the more successful we are likely to be.

For living we have at our disposal one of the most complex and marvellous of organisations; is it not obviously to our advantage to know something of its working when a mistake made through ignorance and easily preventable by knowledge can have as its consequence a life-long handicap? May I remind you of the usual comparison to-day of the human body and a motor car. By the time a human being reaches the age of twenty it is reckoned that in actual cash he has cost his parents and the State at least something in the neighbourhood of £1,500, and those who pay heavy bills for schooling, clothing and holidays will realise that is indeed a minimum
Rolls a science am much a
Either the continually in is is schools Conditioned is In physiologist) physiologist possibly subject an person it fundamental that a that
amount specifically necessity, figure, physiology which it it healthy. and definitely taught Physiological taught — reflexes,’ considered admirable to hypothesis to taught teachers— though blindness study
have gained its space in the press. ‘ Conditioned reflexes,’ a subject first described and elucidated by the great physiologist, Pavlov, again achieves publicity when referred to in another section!

Another point is possibly that there are not enough properly trained teachers available in schools to deal with this subject, and therefore authorities and teachers, being afraid of it, seem to be inclined to think it is not there. Those who have had opportunities of teaching physiology in forward-looking schools, know that children find it an interesting subject.

In the press, generally, the same attitude is seen. In the very abundant reports of Mr. Wells’ Presidential Address to the Section of Education, columns are devoted to his criticisms of history teaching. Practically no paper mentions that among the subjects he thought must be included in any enlightened school was physiology. Finally arises the question as to
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whether the physiology taught has been the right kind. Perhaps it has been too detailed. For general consumption only the simple elementary principles should be taught, especially in their application to healthy living.

Now let us consider the practical value of a knowledge of the body's working and the part it should play in the maintenance of health and the prevention of disease. There are two ways in which this will be of obvious importance. Directly, it will help the individual to know how to live healthily and how to adapt himself to varying conditions, and by its effect on individual behaviour it will influence the health of the community. Indirectly, it will provide an informed public to influence the promotion and control of legislation which affects the health and well-being of the community. As an instance of its value I will quote one set of figures from the last Annual Report of the Chief Medical Officer of the Ministry of Health. (Incidentally may I strongly recommend a study of this report to those interested in the state of public health.) Dr. MacNalty maintains the tradition set up by his predecessor, Sir George Newman, in writing reports which go far beyond statements of figures and of statistics and give interesting information as to recent discoveries and new fields of public work.

Most people are aware of the fact that during this century there has been a most satisfactory fall in the rate of infant mortality. Last year it was the lowest yet recorded for this country—57 per thousand. (In South Australia, to which I was invited last year for a Conference on Infant Welfare, held as part of the Government's Centenary celebrations, the rate is only 32 per thousand, and in New Zealand just lower—31 per thousand.) What this improvement in rate means in the saving of life is shown very strikingly by a comparison of the deaths actually recorded with the number they would have been had the rate remained as it was from 1901-10, 128 per thousand. The actual deaths in 1935 were 34,092, but at the earlier rate would have been 76,664: that means there has been a saving of 42,549 infant lives. No doubt several factors contribute to this: improved sanitation, housing and feeding; but most authorities agree that it is chiefly to be attributed to education and to instruction given in the Infant Welfare and Maternity Centres and Clinics. This is a fine example of what can be done by education, and it is starting at the right end. But if we put the question, 'Is this enough?' there can be but one answer. It is not enough. We have only to look round to see that the after development of these babies, so many of them really lovely and bonny at the start, has fallen far short of what it might have been. No doubt again there are many factors all playing their part in the failure to reach the optimum: lack of knowledgeable care and proper environment in the pre-school years—to be remedied largely by adequate provision of nursery schools. The national and racial type may be changing to one of a smaller physique, though against this can be set the dramatic and almost phenomenal increases in growth that are sometimes produced by attention to diet. Employment at too early an age under unsuitable conditions as regards hours, environment and feeding, certainly plays its part in preventing development up to possibilities. These conditions would tend to disappear with physiological thinking on the part of authorities. (The smaller size of the citizens of the industrial north as compared with other parts of the country is suggestive in this direction.) But undoubtedly a most, perhaps the most, important factor is lack of interest in physical fitness and lack of knowledge of the conditions necessary for proper development, found in the individuals themselves and in those responsible for the conditions of others. Health is something more than absence of disease—
a standard too often accepted as satisfactory—it is the condition of the body which gives zest and joy to living. How short of that our standard is, is indicated by the fact that we speak of a particular individual as being so alive! Surely we should all be alive!

The conditions necessary are comparatively simple: right feeding, exercise, rest, sleep, fresh air, and sunshine, but education is necessary to show what are right feeding, proper exercise and adequate sleep and rest, and even how to make use of sunshine. What lasting harm is often developed in the early years by bad posture, improper use of eyes, by mouth breathing, and by inadequate sleep and rest! In industry, examples of the way in which attention to quite slight unsuitable conditions has improved the health and increased the output of the workers could be given over and over again from the records of the National Institute of Industrial Psychology, which might almost have been described more correctly as the Institute of Industrial Physiology. (Dr. Lockhart will tell you of the need for this knowledge also in the proper management of the workers who, behind the factory buildings and the machinery, are the essential factors in production.)

A good foundation of general physiological knowledge is necessary before there can, or at least before there should, be any attempts at dealing with disturbances of mental processes, and yet many who would hesitate to tackle a simple physiological problem do not hesitate to deal with a psychological one. Quite often a physiological difficulty lies at the root of the 'psychological.' A person suffering from indigestion, for example, usually has a much more gloomy outlook on life and is a harder person to live with than one who has given his digestive processes a fair chance. In fairness it must be admitted that mental processes may be the cause of what are generally regarded more definitely as physical processes. Failure of digestion may be caused by emotional disturbances. Examination by X-ray after a test meal will show complete cessation of movements and of secretion if any strong emotion such as anger, pain, extreme anxiety, is aroused. All of which goes to show the close relationship between the activities of the nervous and other systems of the body.

The proper place to begin physiological education, to teach the science behind the practice of health, is of course the school, but education must not stop there. It is vitally important that everyone should know something of it for his own physical welfare and to enable him to take a proper share in developing the health and well-being of the community. There are many cases in which this knowledge would make for wiser decisions in that important branch of municipal and national government, the public health service. So much of government touches the well-being of the individual, where even a moderate knowledge of physiology, and still more of the biological outlook that comes from this, would be of the greatest value, especially to legislators and Members of Cabinet. It is not enough to call in the expert; in addition there should be sufficient knowledge to enable authorities and individuals who have to carry out the recommendation to evaluate the arguments brought forward by the expert. Compulsory examination in elementary physiology for M.P.s and for Health Committees in Local Government might have splendid effects!

Of the problems that are discussed with so much heat, such as birth control and sterilisation of the unfit, how many of the general public have the knowledge to be able to consider critically the arguments for and against these measures?

A little time ago a private Member’s Bill was introduced into the House to control claims made in advertisements of various proprietary medicines.
DISCUSSION

No doubt this would be good, but how much better to have a public sufficiently instructed to judge for itself. When the general public is convinced, by knowledge and experience, of the value of liquid milk, will they not do something to see that Government control leads to announcements not of a rise but of a fall in its price? In these and in other directions such as tariffs, production and import of food-stuffs, housing, unemployment and relief payments, which all have their physiological aspect, vaccination, diphtheria immunisation, an instructed public could do much to raise the standard of the national health. To-day, therefore, more than ever it seems true to say that the proper study of mankind is man.

I do not expect the millennium to come in this way, but to give people the possibilities of the happiness that goes with real health is not a bad beginning towards its achievement.

Dr. H. E. Magee.—The importance of physiology education from the cultural and utilitarian aspects.

The subject of this discussion involves consideration of the purpose of education in general as well as of the case for the inclusion of physiology amongst the subjects intended for the education of the people as a whole. Education may be looked upon from the cultural and from the utilitarian standpoint. Few people to-day—perhaps very few—would subscribe to the purely materialistic conception of learning so well expressed by Locke in these words, 'It is very seldom seen that anyone discovers mines of gold on Parnassus. It is a pleasant place but a barren soil.' Moreover, few would agree that the aim of all education is purely cultural. The majority most probably regard both objectives as essential to any educational system, a conception fairly accurately expressed in this saying from Cicero, 'Accordingly as soon as we escape from the pressure of necessary cares, forthwith we desire to see to hear and to learn; and consider the knowledge of what is hidden or is wonderful a condition of our happiness.' This implies that attention must first be given to the demands of our animal existence, because, only when these are satisfied, would we be in a condition to 'desire to see to hear and to learn.' But, although training with a view to the satisfaction of our material needs may be regarded as the primary function of education, there can be no question about this being inferior to the cultural aim. The desire for knowledge of objective reality, that is of truth, of whatever kind, is inherent in the human mind and truth is indeed the proper object of the intelligence. The highest value of education, therefore, is the cultivation and development of the intellect so as to enable it to apprehend and appreciate a knowledge of truth. The cultivated intellect, according to J. H. Newman, 'is a good in itself, brings with it a power and a grace to every work and occupation which it undertakes, and enables us to be more useful and to a greater number.'

We have now to consider whether these objectives would be attained by the regular teaching of physiology in schools. That it has a cultural value is clear from the following quotation from Jacks, who, speaking of the education of the body, said 'The highest attainments of the human spirit require the body as well as the mind to be enlisted in their pursuit. It is a principle with a very broad application. It applies not only to the high attainments of the mystic, the genius, the creative thinker, but to the everyday virtues of the common man: self-respect, self-control, courage, trustworthiness, decency and clean conduct in general. These also are unattainable unless the body as well as the mind is enlisted in their pursuit.' Co-operation of mind and body implies harmony between the activities of
The two, and this can surely best be attained when the individual possesses a knowledge of the operations and capabilities of both. Knowledge of the body and how it functions may be considered an end in itself. Thus the experimental physiologist who spends his time trying to reveal the secrets of the bodies of living animals is primarily concerned with discovery of facts and the interpretation of their significance rather than with mere material reward. The thrill of having added to knowledge is his chief satisfaction and is an inspiration to further efforts. If this were not so, few, if any, would choose a way of life fraught with so many difficulties and disappointments. Only a small minority can be experimental physiologists; people in general cannot participate in the satisfaction which a new discovery gives to the scientist. Are people in general then likely to derive any intellectual benefits from the study of physiology? The answer to this is that physiology is a branch of knowledge and that the various branches of knowledge, although each of them is incomplete in itself, together form a whole which is nowhere contradictory provided it is based throughout on objective reality. The study of physiology, therefore, in common with other branches of learning, cannot but help to promote the orderly development of the human mind. To know something about our bodies, the purpose of the various organs and how they function, are objects worth pursuing for themselves, in that they go to satisfy our inherent desire for knowledge. It is a good thing to satisfy this desire, for only through an understanding of the laws of his nature can man hope to use his body properly and to avoid abusing it. I refer here especially to the physiology of reproduction. In this instance, ignorance is not a virtue but a danger, and it is better that young people should be properly taught to understand the human organism than that they should be left to inform themselves from undesirable sources or that they should risk moral damage through prurient curiosity.

The practical end is and will probably remain the chief reason for teaching physiology because, 'as the master-key of medicine, its practical value is self-evident.' But examination of the relationships between physiology and other branches of medicine is not the purpose of this discussion, it is the practical value which an elementary knowledge of the subject would have for the community. There can only be one practical aim in educating the public in physiology, namely, that through a better understanding of the functions of the human body habits of healthy living may be established which would result in the raising of the general level of health and physique. There are few activities of our daily lives on which a knowledge of physiology could not be brought to bear, but I must confine my remarks to certain aspects of life selected on account of their importance to the individual and the community. I shall therefore deal mainly with those periods of life which are the most important for national well-being, and I shall indicate the errors in some popular practices by way of illustration of the dangers to health attendant on misapplication of scientific knowledge.

There is or was a disposition on the part of many to regard mothercraft and housecraft as occupations demanding little intelligence and education and of lesser importance than other careers opened up to women on an increasing extent in recent years. Those who hold this view ignore the great truth there still is in the old adage—'The hand that rocks the cradle rules the world.' The dominant role played by parents in laying down the foundations for health of our future citizens needs no proof. The child is so completely dependent on its parents, and particularly on its mother, that it is true to say that the future of the nation depends more on the influence of the home than on any other factor. These grave responsibilities
and the manner in which they are discharged is so fundamental for the national welfare that the proper equipment of parents for these tasks demands the serious attention of all thoughtful people. The care and feeding of a baby is practically a full-time occupation and one to which an elementary knowledge of physiology, and especially of nutrition, could be applied with great profit. It may be argued that maternal instinct is a sufficient guide to mothers, but many human instincts are vague and fallible, and whatever part instincts play in human affairs they cannot compensate for lack of knowledge, since knowledge is of a superior order to instinct. Instinct, for example, might inform a mother that her own milk is the proper food for her infant, but it could not be expected to tell her that cows’ milk is relatively deficient in iron or that the ‘cream line’ gives little indication of the nutritive value of cows’ milk. Again, instinct does not tell us that heat regulation is not properly developed in the human infant until some months after birth, and it is well known that ignorance of this fact frequently leads to harmful over-clothing of infants through misplaced maternal zeal. Moreover, even if our instincts sufficed to guide us unerringly in the nutrition and nurture of children, they might at any time be overruled or reversed by faulty reasoning based on erroneous information.

A very important recent advance in physiology is the discovery of the influence of the diet of the mother during pregnancy on the physique and health of her offspring and on the nutritive value of her milk during lactation. The diet of mothers at these times is one of the fundamental determinants of the health and physique of the coming generation, and the instruction of future mothers in dietetics is therefore essential to any modern system of education. Further, the health of the child in pre-school days is almost entirely in the hands of the mother—she feeds it, clothes it, and attends to its every need. Whether she does these things well or ill depends to a very great extent on her knowledge of the infant’s needs, and this can only be acquired by learning the elements of physiology and hygiene.

During school life the child is still dependent on its parents for material things, but intellectually parents are only one of many sources from which it attempts to satisfy its insatiable desire for information. The intellect at this time is little more than a receptacle for all sorts of information and is very little used, as it is in adult life, for critical and discriminating examination. The child picks up most of his information from his parents, teachers and companions, but his parents and teachers have the greatest influence with him. School-time and adolescence is the great formative period of life so far as habits are concerned. During this time ‘the organism grows to the mode in which it is exercised’ and habits are formed which determine in very large measure the future career and health of the individual. The importance for the public health of establishing habits of healthy living is self-evident. It is true there is, in the teaching of elementary physiology to children, a risk of that excessive introspection which is the father of fads and prejudices, but the preventive of these is more and yet more knowledge. Assuming proper upbringing, the maintenance of health for the adult is mainly a personal matter, but long standing habits still dominate. If not conducive to health these can be broken by will-power, but the exercise of the will presupposes knowledge of the harmfulness of the habits. The person who is unable to discipline his passions and emotions is their plaything and sooner or later will fall into bad health and become a less useful member of society than he would otherwise be. Within the limits imposed by heredity good health depends first on knowledge and then on self-discipline: both of these are essential.
The health and development of present and future citizens of the country are concerns of the greatest importance for statesmen, teachers and parents, and indeed for every member of the community. The natural physical endowments which come to us from our parents may be frustrated in their development through lack of knowledge or proper care during the years when the body is plastic and capable of cultivation. If it is to develop to the limits imposed by heredity, all its needs for growth must be adequately met. We need not attempt to produce heavy-weights out of children whom nature intended to be jockeys, that would be futile; but we can see to it that the requirements for food, clothing, shelter and nurture of all children are adequately met, so that they may attain that measure of physical perfection which is their natural heritage. While we cannot ignore the importance of economic factors in achieving this ideal, it is true to say that the matter is otherwise mainly one of applied physiology.

There is justification for the complaints made by scientists in recent years of the application of their discoveries to purposes other than the universal good of mankind. Although these criticisms have mostly referred to discoveries in physics and chemistry, the physiologist can also complain that many of his discoveries are misunderstood or else the good which they are capable of conferring is abused through over-indulgence or, perhaps more frequently, through lack of judgment. I do not claim that physiologists always practise what they preach any more than the rest of mankind, but it is nevertheless their duty to point out misapplications of physiological discoveries whether or not they themselves are deserving of criticism. A recent discovery which is undoubtedly abused at present is that of the health-giving effects of sunshine. The ultra-violet rays of the sun tone up the body generally and lead to the formation in it of vitamin D which is essential for normal metabolism of calcium and phosphorus. Like other good things in the world, this one should be used with discretion and wisdom, but the trend of fashion at seaside resorts, and elsewhere, gives increasing evidence of disregard of these precautions. These benefits can be obtained without overstepping the bounds of propriety or without exposing the body to the extent of causing pyrexia, hyperaemia, and desquamation which are definitely harmful. Good health does not necessarily depend on the presence of these effects or even on intensity of pigmentation.

Self-discipline is essential for health but it may be misdirected. Good examples are to be found in the self-imposed dietary restrictions of many modern young women. Deposits of fat in the body so excessive as to interfere with normal functions are harmful, but irrational abstention from certain articles of diet in order to attain slimness of figure may be even more harmful. There are many inconsistencies in the dietetic preferences of the modern devotees of the present slimming craze. Many of them abstain from wholesome and health-giving foods, such as potatoes and even milk, and yet consume relatively large amounts of sugar in the form of confectionery, sweet cakes, and biscuits. Again there is apparent a growing distaste (not confined to those who would be thinner than nature intended them to be) for animal fats as such, and at the same time an increasing desire for pastry and sweetmeats rich in fats so refined and processed as to be practically devoid of all the natural fat-soluble vitamins. It is a curious fact that this prejudice against animal fats exists at a time when the consumption of fat in all its forms is higher in this country than has ever been reported. A little knowledge of dietetics, tempered with common sense, would most probably result in the elimination of many of the prevailing dietetic absurdities, with a consequent improvement in health and, certainly, economic betterment of large numbers of people. The numerous varieties
of slimming foods (a contradictory designation, for no food per se can reduce body weight) are generally more expensive than less refined natural foods.

Exercise is essential for health, but it should be taken with due regard to the physical capabilities of the person concerned, and, to be beneficial, exercise demands suitable amounts of food and rest. In the present enthusiasm for physical culture, a sense of proportion is essential, otherwise the desired improvement in health and physique may be attained at the expense of the culture of the mind. It may, therefore, be necessary to remind ourselves from time to time that the mind and its faculties are of a superior order to the physical body, and that character and grit are derived from mental rather than bodily culture. The ancient Greeks, with whom culture of the body was almost a national gospel, recognised the need for subordination of athletics to mental culture. Plato, for example, was not complimentary to professional athletes when he said, 'Have you not observed that they sleep through their life and if they depart but a little from the appointed regime at once they are quickly and seriously ill.' The civilisation which produced Achilles, Lysander and Alexander also produced Socrates, Plato and Aristotle. There is room for both athletes and sages in civilised society. Physical exercise should be regarded as recreation in the literal sense of the word, the re-creation of mind and body in order that they may be the fitter to cope with the more serious matters of life.

Finally, I wish to refer to the official attitude towards instruction in physiology and hygiene. The Board of Education has issued comprehensive directions for instructing children in the ways of health in an excellent little book, Handbook of Suggestions on Health Education, which deserves to be more widely known. The main purpose of the book is to encourage teachers to create in the minds of boys and girls during the years of adolescence, an understanding and cultivation of health. It presents health as an ideal, the inculcation of which is no less important for national life than is that of the ideals of truth, goodness and beauty. It deals, amongst other things, with the relations between body and mind, nutrition, ventilation, exercise, mothercraft and infant welfare. The existence of this book may come as news to some, and to those who feel inspired with apostolic zeal for the teaching of these subjects, it might be as well to suggest that they should seek for converts elsewhere than in the Board of Education. This book proves that the Board is already converted.

The standard of excellence in the teaching of these subjects in many schools I have visited throughout Great Britain would probably surprise most people, as it did me, and augurs well for the health of the next generation, provided the knowledge now imparted to the mothers of the future is used with wisdom and prudence.

Finally, a tribute is due to the British Broadcasting Corporation for the good work it is doing in health education and in general culture by means of its talks on biology and physiology to children.

Prof. R. C. Garry.—Human physiology in the teaching of Biology.

The health of the individual and of the community depends to a large extent on the proper application of physiological knowledge. In the past, medical and public health authorities, from their knowledge of advances made by physiologists, issued dogmatic statements for the guidance of the public. The public, on their part, usually accepted such ex cathedra pronouncements quite uncritically.

Such methods, however, savour more of a dictatorship than of a democracy, and they are probably inefficient.

To take one example, all the slogans and posters of the Milk Marketing
Board will, in the long run, be futile unless the public understands why it is important to 'drink more milk.' When the novelty wears off, 'Ballyhoo' loses its effect. But intelligent understanding is permanent. The public must have some knowledge of the proper nutrition of human beings before the efforts of the Milk Marketing Board can hope to reap their full reward.

How, then, ought the public to come by such necessary physiological knowledge?

By means of instruction during the school years, I feel, since the adult education movement reaches but a small fraction of the whole community. Moreover, I am not happy about many popular books on physiology, least of all books on dietetics and nutrition. So often the uninstructed reader falls victim to the crank and faddist.

So, the already overcrowded school curriculum is to be saddled with yet another subject, human physiology?

I doubt if it can be done.

But, can't we discard a certain proportion of the biology already taught in school and in its place put human physiology with all its implications for human welfare? After all, physiology is a biological subject. And, dare I suggest it, could not some of the time devoted to chemistry and physics be better employed in teaching biology with this emphasis on the human organism? During the past four years such a course in biology has been elaborated for broadcasting to schools, the course given by Prof. Peacock and myself.

Not only was human physiology an integral part of the course, but instruction in human physiology also preceded in time the more conventional instruction in biology. For example, structure of the human body was dealt with before structure of the lower forms of life was described. Respiration in man, and by implication in all mammals, preceded discussion of respiration in, say, fishes, insects and plants.

At first sight, this seems to 'put the cart before the horse.' It does, if one accepts unquestioningly the usual academic course in biology, the course which starts with the amoeba and finishes with the elephant. To my mind, such a course is justified in one curriculum only, that for the medical student who receives adequate instruction in human physiology at a later stage in his course. But, for all other students taking a course in biology, the omission of human physiology is a most grievous fault. Such students have omitted from their curriculum the organism about which most is known. And, to make matters worse, these students of biology are the future teachers of biology in the schools where some instruction in human physiology is so essential.

In the schools themselves, until within recent times, human physiology was taboo. Science, in the form of chemistry and physics, usurped all the time which could be spared. Then 'Nature Study' appeared, a girlish pursuit, or, at least, one more in favour in girls' schools than in boys'. To normal boys 'Nature Study' is an effeminate affair, and the nature study class, derisively, 'Bug-hunters.' Such imponderables are not without weight.

It is here, I think, that human physiology can step in, redress the psychological balance, and make biology attractive to all children and thus impart much needed knowledge to the citizens of the future.

How does such a human physiology-biology course work in practice? From the pedagogic point of view it is certainly sound. It deals with the familiar human body first of all; but, can such a course teach first principles? is there scope for practical work without the need for expensive apparatus? is it free from objectionable features?
Let us take possible objections first. Vivisection, however important in the academic teaching of physiology, need play no part in a course such as I visualise. Secondly, will the pupils develop a morbid awareness of the workings of their own bodies? I do not think so. Knowledge of the normal should do no one any harm. The medical student develops his hypochondriacal ills only after he starts the study of pathology, medicine and surgery.

However, teaching of human physiology to what one may call a lay audience does demand care. A school teacher fussily insistent on the importance of daily evacuation of the bowels may create an impossible situation. But that is a risk which should be run. I believe that proper school instruction in nutrition and dietetics, with, of course, practice of what was taught, would halve our national bill for purgatives within a few years.

Now for the biological first principles. The human body is ideal for the teaching of facts about growth, movement, alimentation, respiration, circulation. But I have doubts about reproduction and excretion. I know it is all wrong, but it cannot be helped. I am afraid of the earnest self-conscious teacher and the uncomfortable self-conscious pupil if these two principles are tackled by direct reference to man. It can be done, as I have done it, through the comparatively impersonal medium of broadcasting, but——. So these two first principles of excretion and of reproduction are best tackled by reference to lower forms of life. In the future we may be more sensible.

Now the last problem of practical work, and it is relatively simple. There is no need for elaborate apparatus.

May I give one or two examples of the type of practical work which succeeds in broadcast courses and in adult education work where the pupils, although grown-up, are receiving instruction in biological science for the first time.

Let us take the practical work in a, shall we say, 'physiological' order.

*Alimentation, food and digestion:*

An institution teaching chemistry can make quite a feature in practice of the simpler test-tube reactions characteristic of the proximate principles of food, and the action of saliva on starch serves very well as an example of enzyme action. After that, digestion in the amœba becomes less of a text-book myth.

Using any of the standard food tables, analysis of weighed portions of the commoner domestic food-stuffs, of fruits and of vegetables, in terms of water, proximate principles, and of vitamins, makes quite an instructive exercise.

*Circulation:*

I see no reason why palpation of the pulse, even listening to the heart with a stethoscope, should not be used in teaching the facts of the circulation to quite young people. Older pupils can be asked to graph the effect of exercise on the pulse, and to observe the effect of skin temperature on skin colour. But I should omit blood pressure observations—partly, since a sphygmomanometer costs money, and partly, since the general public is far too blood pressure-conscious already. And examination of a drop of human blood has a vividness and reality quite absent from contemplation of a jar of ox blood from the slaughter-house or blood from a dismembered frog. Stained human leucocytes are more real than the story of Metchnikoff and his phagocytes.
Respiration:
The respiratory system offers great opportunity for simple experimentation. Breathe on a sheet of cool glass to show that the expired air is saturated with moisture, and breathe through lime water to show that a living organism excretes carbon dioxide. Have the ‘tough guy’ of the class show off his chest expansion by means of cyrtometer tracings—two bits of gas piping joined with rubber tubing are quite adequate. The rate of respiration before and after exercise is instructive, and the period of voluntary apnoea, first of all after deep breathing and then after exercise, gives much material for teaching. And it has a vital reality for human beings which all talk about fishes’ gills totally lacks.

Nervous System:
The nervous system, unexpectedly perhaps, gives a wider scope for elementary practical work than any other. Simple reflexes, such as the knee jerk and the Achilles tendon jerk, are good material, so also are the eye reflexes. The senses, too, offer good opportunities for practical work. In the skin there are the senses of touch, pain and temperature, the ear and labyrinth give opportunities for the physiologist and the physicist, while there are a whole host of practical exercises in connection with the eyes. I am thinking of the horizontal field of vision with one and with both eyes—a string, a piece of chalk, coloured papers, and a bench top suffice. There is the existence of the blind spot to demonstrate, the facts of visual acuity, stereoscopic vision and various simple optical illusions. Why should children be taught more about flies’ eyes than about their own, more about the spectrum than about colour vision? Work with the senses, too, tends to correct the crude and unthinking materialism which a study of chemistry and physics, and even of conventional biology, is so apt to inculcate.

This, then, is my thesis. For man, the rational approach to biology is through study of human physiology. It imparts a foundation of knowledge absolutely essential for every citizen of a democracy, it is good science, good biology, and is admirably adapted to school instruction.

Dr. L. P. Lockhart.—Physiology as a part of general education.

This contribution to the discussion (for summary of which see p. 412) has appeared in full in Lancet, 2, 1177, 1937.
DISCUSSION ON

PLANNING THE LAND OF BRITAIN.


Joint Discussion by Sections C (Geology), D (Zoology), E (Geography), F (Economics), K (Botany and Forestry), M (Agriculture), on Tuesday, September 7, 1937.

Lord Trent said that, before introducing the first speaker, he would like to emphasise some of the difficulties that must be considered in any attempt to plan the land of Britain, the objectives of any such plan being to increase the production of home food supplies on a staple basis, to build up an agricultural population living under conditions of reasonable comfort and security, and, though less vital, to find reasonable facilities for the rural recreation of those who live in cities. The difficulties in the way of the first objective are the weather (which cannot be planned), the time factor (for the rearing of live-stock and crops cannot be speeded up as can machinery), and the conservatism of the British farmer. A real difficulty in the way of the second objective is that the people we may want to put back on the land may not wish to go back. Agricultural work as compared with work in cities is less remunerative, more arduous and lacking in amenities. If drift to the cities is to be checked and remedied, work in the country must be made more attractive. Linking this question with that of rural recreation for urban populations, there is the danger that town dwellers, ignorant of rural conditions, may come to look upon the land purely as a place for enjoyment and not as a place for work. One method of inculcating in town dwellers a healthier regard for the country would be the institution of short periods of compulsory service by young people in labour camps.

Dr. L. Dudley Stamp, believing that each of the sciences represented by Sections of the British Association has a definite and vital contribution to make concerning the future use of the land, proposed to restrict himself to the viewpoint of the geographer. Any planning of the land of Britain must start from the present position—the present utilisation of the land. This utilisation is extremely complex, as a result of a long period of settlement, comprehending a long-continued process of trial and error. Dr. Stamp placed in three main groups the factors which have brought about the present position: (1) natural or geographical, (2) historical, (3) economic.

The natural or geographical factors are fundamental, and contrary to
popular belief they tend to become more, not less, important. In medieval Britain, communities isolated by the absence or bad state of communications were necessarily more or less self-supporting, and had to use the land they had to the best advantage possible, even though neither their land nor the climate were really favourable. With development of transport and communications there developed a natural tendency for each part of the country to be devoted to those uses for which its natural features fitted it.

Therein lies the whole secret of planning. To study the factors involved is to determine the optimum use of every acre of land in the country; and such planning is concerned with far more than mere production. The land must be used for the satisfaction not merely of the material but also of the social and aesthetic needs of all sections of the community.

In passing, it is to be observed that the improvement of communications has led to the gradual concentration of production of certain commodities, of which wheat is a salient example, on areas most suitable for their production, not merely in this country but in ‘new’ lands overseas more suitable still. This process has resulted, in the first place, in the abandonment of the cultivation of crops for which Britain is not naturally suited, and, in the second place, in the abandonment of land formerly cultivated in densely populated Britain. The influence of improved communications does not apply to Britain alone, but to the world; nevertheless, present-day development is largely within units determined by tariff-walls, and that in itself justifies discussion of planning the land of Britain in something of isolation from the rest of the world.

The natural factors to be considered in relation to planning are: (1) position and accessibility, (2) physical structure of the country, including drainage, (3) soils, (4) climate.

Inaccessibility has led to depopulation in all the remoter parts of Britain; and the question of accessibility bears closely upon the position of National Parks (a subject dealt with by more than one subsequent speaker). The subject of physical structure Dr. Stamp referred to the speaker following him, Prof. P. G. H. Boswell, merely indicating the strong contrasts between the various physical divisions of our small country. In regard to soils, he pointed out that Britain has as yet no comprehensive soil survey. In Russia and the United States, despite their greater areas, much more work has been done in this direction. Our own need of such a survey is great, if only because we possess strictly limited areas of really first-class soil, a precious heritage which planners, till now, have done little to protect; yet such areas should be protected—as, for instance, where they supply fresh fruit and vegetables to neighbouring towns. As for climate, the position of Britain is such that within it the limit of cultivation of various common crops—wheat, for example—is found. In the cool summers of the north, wheat may not ripen. There is a difference also, sufficient to affect agriculture, between the dry east and the wetter west. A crop suitable in one part of the country may be one not to be encouraged in another part.

Historical factors have a general tendency to stabilise the use of land. In some parts (Norfolk, for example) stretches of arable land are seen to be interrupted by tracts of permanent pasture, although there is no change in the soil. Such tracts may represent, or include, great parks laid out in days when economic conditions were more favourable to landowners than they are now, and some are, or may become, of incalculable value to the nation when they pass from private to public ownership as open spaces adjacent to great cities. So, also, waste lands too poor for cultivation have become commons dedicated to public recreation.

The use of the land of Britain is influenced at present by a policy tending
towards economic self-sufficiency; but economic factors can only operate within certain limits allowed by natural factors. The accompanying table indicates the present use of the land. In Britain one-third, and in Scotland over two-thirds of the surface fall within the category of rough grazing, heathland, and moorland. These lands may be regarded as the problem lands of the future. Woodland covers only 5 per cent. of the whole surface of the country; Britain produces a minute proportion of its own timber requirements: yet Britain has a forest climate. Orchards represent 0·5 per cent.; that figure should be considered against the value of fresh fruit to the nation. Of essential food requirements the country produces some 35 to 40 per cent., of wheat less than 15 per cent., of meat 44 per cent. The table indicates what might be done, not by any radical changes in the use of the land, but by reconditioning each type of land so as to improve its quality and utilisation. Of the rough grazing, heath, and moor, something like a third could be converted into grazing, a third could be forested, and a third would be left for recreation, sport, and national parks.

Dr. Stamp believed the process of reconditioning to be both essentially desirable and economically possible. He referred to the chairman's point that in the event of a national emergency the processes of nature are such that changes cannot be made suddenly. National emergency does not necessarily connote war: the changing character of world trade and the possible diminution of overseas markets for British-manufactured goods may throw us back upon the resources of our own land. Furthermore, a new standard of values—nutritional values—is beginning to be appreciated. Fresh fruit, vegetables, meat, and milk, imply home production. Again, increasing leisure and a rising standard of living make new demands on the land: good land for gardens and allotments; the preservation of accessible tracts which are agriculturally submarginal, and the protection of the finest scenic areas as national parks—for example, the Lake District, the Peak District, Snowdonia, the Cornish coasts. Much might be done for the beautification of Britain—the abolition of ribbon development and the substitution of a 'parkway' treatment of arterial roads; the plantation of woodland on more natural lines than those of regimented conifers; the obliteration by the planting of trees and shrubs of such scars as the worn-out parts of the Black Country or the deserted Shropshire coalfield. Such changes could be made at relatively small cost, if carried out with accurate knowledge.

<table>
<thead>
<tr>
<th>Present Use</th>
<th>Per cent</th>
<th>Use after Reconditioning</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable (intensive)</td>
<td>2·0</td>
<td>Arable (intensive)</td>
<td>5·0</td>
</tr>
<tr>
<td>&quot; (farm crops)</td>
<td>20·0</td>
<td>&quot; (farm crops)</td>
<td>26·0</td>
</tr>
<tr>
<td>Permanent grassland (good)</td>
<td>10·0</td>
<td>Permanent grassland:</td>
<td></td>
</tr>
<tr>
<td>&quot; (other)</td>
<td>21·0</td>
<td>First-class</td>
<td>16·0</td>
</tr>
<tr>
<td>Rough grazing in enclosed fields</td>
<td>9·0</td>
<td>Other</td>
<td>22·0</td>
</tr>
<tr>
<td>Heathland, moorland and other rough grazing</td>
<td>26·0</td>
<td>Heathland, moorland, etc.</td>
<td></td>
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<tr>
<td>Forest and woodland:</td>
<td></td>
<td>Forest and woodland:</td>
<td></td>
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<tr>
<td>For timber</td>
<td>2·5</td>
<td>For timber</td>
<td>11·5</td>
</tr>
<tr>
<td>Other economic</td>
<td>1·0</td>
<td>Other economic</td>
<td>2·5</td>
</tr>
<tr>
<td>Scrub land, etc.</td>
<td>3·0</td>
<td>Scrub land, etc.</td>
<td>0·5</td>
</tr>
<tr>
<td>Orchards</td>
<td>0·5</td>
<td>Orchards</td>
<td>1·5</td>
</tr>
<tr>
<td>Residual (housing, industrial, etc.)</td>
<td>5·0</td>
<td>Residual (allowance for improvement of housing, etc.)</td>
<td>6·0</td>
</tr>
</tbody>
</table>
No one Government Department has care of the land of Britain as a whole. The Royal Commission on the location of industry has a task which implies a complete planning of the whole country. The institution of a permanent advisory scientific committee might properly be recommended on the ground that natural factors control the planning of the land. The study of natural factors is the concern of Sections of the British Association, and that body might well form its own committee of expert opinion to work together for the benefit of the whole country.

Prof. P. G. H. Boswell, O.B.E., F.R.S. (speaking at short notice in the place of Prof. H. L. Hawkins, F.R.S.), said that it is probably true that in no other area in the world, size for size, is there such a variety of rocks exposed as in Britain. He outlined the four broad divisions of the geological column—the great eras of the pre-Cambrian (with few or no traces of life), the Palaeozoic (with evidence of ancient organisms), the Mesozoic, and the Cainozoic (the era of recent life, culminating in man). The broad distribution of the rocks of these several eras is as follows. The pre-Cambrian occupies the area of the Scottish Highlands, north of the Lowland Basin, Anglesey, strips of North and South Wales, and certain smaller but significant areas on the Welsh Borders and in the Midlands. The rocks are mainly crystalline: granites, gneisses, schists, quartzites, etc. The older Palaeozoic rocks occupy the southern uplands of Scotland, the Lake District, the Isle of Man, most of Wales, parts of Cornwall, and smaller areas in the Midlands, and consist of slates, mudstones, sandstones and volcanic rocks of various types.

The newer Palaeozoic rocks, of considerable commercial importance, constitute a belt dipping off the older rocks, and occupying the Central Lowlands of Scotland, Northumberland and Durham, the Pennine region, the Welsh Borderlands, South Wales, the Bristol area, Devon and Cornwall, and patches of country in the Midlands; also the underground of London and Kent. Sandstones, limestones and coal measures are the dominant rock types.

The Mesozoic rocks form still another belt trending roughly north-east to south-west, from the Yorkshire coast to the south coast. They consist of spreads of sandstone and marl, escarpments of limestone and broad areas of clay. The Cainozoic or Tertiary rocks are mainly confined to the Eastern Counties, the London Basin, and the Hampshire Basin, and are marked by deposits of unconsolidated sands, clays and brickearths. Spread as a blanket, but irregularly, over all the land of Britain are the products of the Great Ice Age—gravels, sands and clays—thickest, of course, in the lower ground to the south-east.

Thus from the pavement of oldest rocks in the north-west there dip off to the south-east successive slices or wedges of newer rocks.

In planning for the future, there arise two considerations: (a) the suitability of the land for certain specific purposes, and (b) the desirability of its utilisation in a particular way. These considerations have to be balanced one against another and in relation to the economic development of the country as a whole. In most instances a particular unit of land could be used for several purposes; then the planning scheme should be directed to determining and advising upon the best use. The absence of planning in the past has led to wastage of money, a procedure comparable with the dumping of quarry refuse on the unworked area of good rock and its subsequent removal at considerable cost. The influence of geology upon planning may be conceived to be in large part indirect; but always, in alliance with climatology, it exercises an unobtrusive control over faunal,
DISCUSSION

floral, and physical features, and an influence over utilisation, development, and location of industries. The influence of the rock-types is seen in the scenery, industrial value, and human occupations of any given region, but for the most part the geological factors are factors in the first instance; they are modified locally in many ways to produce what may be termed the factors in the second instance, which are those most relevant to the present discussion.

Nevertheless, certain direct geological influences fall to be considered here. Since almost every important geological formation has given rise, in different parts of the country, to its own characteristic scenery and ecology, we should endeavour to secure, in the course of our planning, that at least one typical area on each geological formation is reserved. In some cases there is an obvious, a unique area: in others latitude in location is given by the extension of the formation across Britain. Here and there a National Park is desirable, but in many instances smaller reserves, such as those secured by the admirable work of the National Trust, would be adequate. Some areas have been, or can be, scheduled under the Town and Country Planning Act of 1932. Examples of such reservations already made are found in the Dovedale area in the Carboniferous Limestone, the Greensand area of West Sussex, the Chalk Downland, and so on. The New Forest, on the Eocene deposits, is fortunately reserved as Crown land for all time. A comprehensive list of desirable areas could soon be compiled.

It is in the areas of ancient rocks—the pre-Cambrian and older Palæozoic—that National Parks would be mainly located, for here the resistance of the rock-types and variety of their arrangement and rearrangement give rise to striking scenery—hence, of course, the pleasure resorts of the Scottish Highlands, the Lake District and Snowdonia. And, dependent on the geology, they carry a characteristic flora, and sometimes a distinctive fauna. They are hard lands for man to make a living on. Mineral resources are not absent, in the form of slate and building-stone industries, small metalliferous mines (lead, copper, zinc, iron, barytes, etc.); but they are scattered and often of no great importance.

The Upper Palæozoic rocks also furnish areas of great scenic beauty suitable for National Parks, as for example in the Peak District. There is no need, in such cases, for large-scale labelling of well-known features such as has been perpetrated at High Tor, at Matlock Bath. A speedy removal of this blemish would be welcomed by the many members of the British Association who have seen it. From the point of view of mineral resources, Britain owes much to the Upper Palæozoic, the Carboniferous Limestone, so important as a raw material for chemical, metallurgical, agricultural purposes and for its iron ore, lead, zinc, fluor spar, etc.; also the Coal Measures, of the constituent rocks of which little is wasted—coals, brickmaking clays, refractory materials, iron ores, building-stones, etc. In the course of unplanned working of this national wealth, it may be felt that the face of the land has been indelibly scarred; yet even the Black Country is a mark of the beast which can be outgrown.

Apart from quarrying of limestones for building-stones and lime-burning, and the working of clays for brick-making, and of sands for refractories, the chief mineral importance of the Mesozoic rocks lies in the iron ores of the Midlands, Lincolnshire and Yorkshire. The great development of the industry at Corby in recent years suggests that here is an admirable opportunity for enlightened planning, just as the Kent coal field, under Abercrombie's planning, has demonstrated the feasibility of developing a large-scale mineral industry without the production of Black Country.

The belt of Mesozoic rocks, like that of the Cainozoic, is best known as
the agricultural region of Britain; and agriculture falls for consideration later in this discussion. But this belt is also important as furnishing our great reservoirs of underground water, particularly in the Triassic Sandstones, the limestones of the Oolites, and the Chalk. Water supply is a basic consideration in connection with the location of industry, which is at present the subject of an inquiry by a Royal Commission. The extension of housing and road-development incidently increases the waterproofing of the land surface and prevents rain from being received into natural underground storage. The local loss is material, as is obvious if it be remembered that consumption per head is rising to thirty or thirty-five gallons per day, and bids fair to increase, and that large works with extensive washing plants consume as much water daily as a city of one or two hundred thousand inhabitants. The disposal of waste products—sewage—and the location of cemeteries also necessitate due regard being paid to the geology of the neighbourhood if the water supply is not to be contaminated. It is unfortunate that the type of sandy or gravelly well-drained country best suited for the location of cemeteries and sewage-farms is that on which we are dependent for the absorption of rain and the renewal of the underground water supply. The appointment recently of a Committee by the Ministry of Health, arising out of discussions and recommendations of the British Association, recalls that the methods of recording overground and underground supplies of water throughout the kingdom are being systematised. It is to be hoped that, when the distribution of the available supplies is known in detail, there may emerge some agreed allocation which will lead to the reduction of opposed Water Bills in Parliament.

Dr. Julian Huxley said he proposed to deal with the preservation of animals in Britain. Anyone who has seen wild and beautiful country such as the great game plains of Central Africa with their original fauna, and the less extensive wild country of certain parts of North America lacking in so much of its original fauna, knows how much richer and more fascinating is the former. To exterminate species is to do something irreparable, and with all our knowledge we cannot produce species which have been exterminated in this country. There was probably justification for exterminating wolves and bears (though a few of the latter might, without difficulty, have been preserved in remote parts of the Highlands), but with less justification the countryside has been impoverished in recent times by the extermination of the great bustard, the avocet and many other rare and beautiful birds, and by the almost complete extermination of the white horse, the great eagle, the pine marten and the beech marten. In planning the land we must see what can be done in a busy and crowded countryside like ours to preserve such animals partly for their scientific interest and also for their value as objects of general interest to increase the amenity value of the country.

With regard to mammals, the position has gone so far that there is little to be done except by setting aside in remote districts certain largish areas as sanctuaries or national parks. With regard to birds and rare insects, the best thing in a country like ours is to set aside comparatively small areas for groups of species having the same habitat. That has been done in quite a wide way at various places like the Faroe Islands, Dungeness, and Wicken Fen. One important thing we should do is to draw up a list of all the existing sanctuaries and of all the species deserving protection, and of places that might be set aside as sanctuaries for them.

Planning of breeding places for introduced animals of a commercial value is a matter which needs attention. A certain amount of land utilisation should be reserved for the breeding of foxes, nutria, etc., and in planning
of this kind the greatest of caution would have to be exercised, the example of the musk-rat being a good illustration of the grave dangers attendant on the introduction of new animals.

In addition to the consideration of preserved areas for special types of animals there is also the question of national parks for the preservation of nature in general, including scenery, geology, flora and fauna. In Britain, as in any other country, conservation must be a compromise between man and nature, and the general opinion of those who are best informed on the subject and have thought, for instance, of the desirability of preserving the fauna, is that it is better to specialise in this matter than to attempt a compromise. That is to say, the interests of man should be paramount over most of the area, and the interests of fauna, flora and scenery paramount over other parts of the area. With regard to any national parks that may be established, a zoological point is that wherever possible some central area should be entirely reserved away from the general public as a real sanctuary, available to wardens and scientists, as a reservoir for breeding insects and animals which could then overflow to the adjoining national park. With regard to national parks in Britain, we must not envisage such areas as primarily for the conservation and breeding of animal life as in Africa and certain parts of America and other countries. We must at first concentrate on providing national parks for recreational purposes where beautiful scenery is available within easy range of great centres of population, but as the national park principle spreads it is to be hoped that a large area will be set aside, say in the Western Highlands, primarily for flora and fauna, and secondarily for recreational interest. The Germans have shown us what can be done in the way of national parks. They have established a magnificent number of very interesting animals, including the white horse, the bear, the beaver, deer, and so on, and they have even produced a close replica of the extinct aurochs, a kind of synthetic aurochs, by breeding oxen and cattle.

Dr. Huxley expressed great satisfaction that the British Association had sent in a resolution urging the Ministry to implement its promise to set up a statutory authority. It is absolutely necessary for some central organisation to look after national parks and that that type of conservation should be set up. It cannot in principle be left, in a country like Britain, to local machinery like the Town and Country Planning Act, for the simple reason that areas wherever national parks were allocated would be poor areas, enjoyed largely by people from other areas. It would be unfair to place such a burden on local rates. It is necessary to have some central authority. It is further necessary to have some central authority to reconcile the claims of various existing statutory authorities which are more or less tyrants in their own domain and which sometimes clash. For instance, there are the Electricity Commissioners, the Forestry Commissioners, and so on, and there is no overriding authority to decide the claims of forestry and recreation or the claims of indigenous fauna and flora.

In conclusion, Dr. Huxley made a strong plea for the drawing up of a list of the most interesting species in need of protection, and a list of the areas most suitable for them, and for the establishment of national parks in some of which, at least, the preservation of interesting flora and fauna could be envisaged.

Prof. E. J. Salisbury, F.R.S., dealing with the botanical aspects of planning, was concerned mainly with the preservation of the amenities of the country, and he referred to gardens, national parks, and roadside planning.
The area occupied by gardens is comparatively small, but interest in gardens is growing rapidly, as instanced by the fact that, whereas ten years ago the Royal Horticultural Society had some 20,000 members, the membership is now 34,000. The growth of gardens has resulted naturally in peripheral expansion, so that we get that condition referred to as hyphenated country, part town, part country. Because they are so scattered and because of their location gardens play a much larger part in regard to amenity than would be expected from the actual area they occupy, less than 2 per cent. of the areas where there is a large population; but as there is too much tendency towards mass production, the effect upon the amenity is rather deleterious. It is necessary only to go through some of our urban areas to realise that most people grow the same cheap plants, and the result is as offensive to the eye as the result of present-day building ideas with houses all looking as if they had been struck out of one mould.

On the question of national parks Prof. Salisbury emphasised the fact that, from the botanical point of view, small areas might be almost worse than useless. If small areas are given to the nation, there is a very grave risk that tours to them will be arranged, and it cannot be too strongly emphasised that mere trampling of vegetation has the effect of altering the species. Opponents of national parks for the preservation of British flora have argued that as, of our 1,800 species, only four have become extinct during recent times, there is no need to make special provision for preservation; but while it is true that there has been little extinction as a whole, it is also true that there has been serious diminution of species in certain areas. It has been found that 300 species have become extinct in one county or another, and some species almost extinct over large areas. It has been said, too, that the opportunity of introduction more than counterbalances diminution, but it should be emphasised that these introductions are for the most part weeds of cultivation, and what we want are native plants which will stand up to the competition of native species.

It is essential that the control of nature reserves should be in the hands of experts, and two examples show the type of problem they would have to consider. (1) During recent years quite 100 new species of beetles have been added to the British list as a result of the study of decaying tree trunks in the New Forest, and, further, these same tree trunks are the source of food for a number of birds and the homes of some common and some very rare fungi. Should decaying logs and tree trunks be destroyed? (2) It is useless to preserve an area by merely leaving it alone. For example, the scrub areas of Britain, considered by some to be the most beautiful parts of the country, represent a transitory phase between grass and forest. The greater part of this country if left alone would pass to forest. That scrub area is the richest in insects and flora of any type of vegetation we have in this country, and we can preserve these features only by removing areas that are coming into their prime, thinning out the scrub and maintaining the changing character. Those in charge of the Wicken Fen reserve know they can maintain that rich fauna only so long as the sedge is properly cut. That involves proper control and considerable expense. So that control and expense are necessary for the maintenance of those reserves.

Roadside planning, like gardens, has an effect on amenities out of all proportion to the area concerned. It is essential that the trees planted and the way they are planted should be such as not to create an effect of monotony, which has been said to have a deleterious effect upon the drivers of motor cars. It is also highly desirable that trees planted on the roadside in rural areas should be characteristic of the area in question, enabling us to preserve many of our native trees in their excessive beauty.
Sir Roy Robinson said that, in the course of his work dealing with the forests of this country, he travels over as much of the land as any man in Great Britain. It is always a source of great amazement to him that land can be wasted in the way it is wasted. Good pastures are found overrun with bracken and foliage and infested and spoilt, and that is the type of land which very often comes to the Forestry Commission to be planted, sometimes undeservingly, with trees.

It seemed to him there are two main branches of planning the land: first, to make the right use of land now wrongly used, and, secondly, rightly to use land already nominally put to the right use but badly managed. The second question is purely one of management, and is relatively easy, but when it comes to the question of saying that a certain bit of land shall be used for this or that purpose, serious difficulties arise. When you come to plan the land in detail you find that the prophet who said how he would have planned Britain thirty years ago would have to eat his words to-day.

The Acland plan for improving and increasing the woodlands of the country is the only plan formed in the days immediately after the war which has been carried out consistently. In the course of that plan the Forestry Commission are trying to do two things, and probably more. An attempt is being made to increase the woodland area by roughly two million acres, and 500,000 acres of plantation have been purchased towards that end. An attempt is being made to get the private woodlands of the country in order. That is a very difficult thing to do, because the owner of woodland to-day suddenly finds that the competition for pulp-wood in North Europe is so great that there are not enough pit props to go round in this country. Pit props are required in case of emergency, because if you cannot get pit props you cannot get coal, and without coal you cannot have steel and other things. That explains very briefly why it is necessary for the State to take a very real interest in the production of timber. The Commission hope to purchase enough timber to be self-supporting for a period of three years.

The mere ownership of large areas of land, which runs now into one million acres, brings with it other things. It has given the opportunity of providing recreational facilities. Such development has been made in the New Forest. A national forest park has been set up at the head of Loch Long and Loch Fyne in Scotland, and another is being opened in Snowdonia. The various areas developed by the Commission become admirable places for deer, and it is probably safe to say that there are more deer in this country to-day than at any time in the past 200 years.

The Commission are trying to keep the pine marten going, and might be quite willing to try putting brown bears in the bigger forests.

Sir Daniel Hall, K.C.B., F.R.S., said he was chiefly concerned with the question of how far we may be able to replan our farming land to better ends than it is used at the present time. The difficulty the farmer has been going through has been how to adapt his industry (and it is a slow, long-period industry) to rapid changes in the environment in which he has got to live. That, and the march of scientific progress, has brought about, to a very large extent, the disintegration of our old farming.

Is it worth while to try and set about the planning of our agriculture? The farmer does not want it. He only asks to be left alone. But he is at the mercy of other forces, and if agriculture is to be preserved it needs replanning. Though there can be found in this country finer examples of farming than in any other country in the world, the industry, taking it
as a whole, is in a very depressed condition, and one can only say that the agricultural land of Britain represents a distressed area.

The history of the past ten years of agriculture is instructive. In that period the total area of cultivated land in England and Wales has lost something like 1,000,000 acres or 3 per cent. of its total area. The arable land, which is the heart and most important part of the thing, has shrunk from 10,300,000 to 9,000,000, a loss of over 1,000,000 acres being 12 per cent. off what it was ten years ago. If we take a particular form of the industry such as small fruit—raspberries and black currants—we find that 69,000 in 1937 have been reduced to 52,800 acres to-day, representing a loss of 24 per cent. Vegetables have increased from 128,000 acres to 150,000 acres, but what is very symptomatic of the depression which has fallen on the industry is that those rough grazings (referred to by Dr. Stamp), which represent the margin of land the farmer thinks no longer worth while including in his cultivated land (though he may let his stock run over them at times), just about 4,000,000 acres in 1927, are 5,500,000 acres this year. There has been an increase in the wastage of cultivated land as well as in the actual loss of the cultivated areas.

The most significant thing in this period has been the loss of working men on the land. In 1927 the regular wage-earning workers numbered 587,000. This year they number 489,000, representing a loss of 17 per cent. in ten years. That loss has fallen most heavily on the youngest section, workers under twenty-one years of age, for, while there were 134,000 of them in 1927, there are only 94,500 to-day—a loss of nearly 30 per cent., which illustrates significantly the progressive decline in agriculture.

Anyone familiar with farming knows that a great deal of the land is not being properly utilised. By what means and by what processes can it be taken in hand? Some look on agriculture as a means of finding a large amount of employment by settling a large number of men on the land, men who become a stable type of citizen, regarded by some Governments as productive of the best kind of soldier. In Germany the land, in places, is being parcelled out, the number of small holdings is being enormously increased, and steps are being taken to tie these men as far as possible to the land, to create 'a peasant aristocracy,' who, by various means, by giving them a certain pre-eminence, will be induced to stay on the land and not be tempted away by economic considerations. There are attempts to forbid, on that class of holding, the introduction of machinery, so that the maximum amount of labour shall be employed.

But to adopt such a national plan is to forgo the full economic use of the land out of which the most food required for the needs of the country should be obtained. There cannot be any doubt at all that material progress in agriculture has generally replaced manual labour by something in the shape of a machine. It may be that the introduction of machinery is the only means of keeping that land in cultivation at all; otherwise, by pressure of circumstances it would drift off into the poorest type of grazing, with practically no employment upon it at all. It must be borne in mind that the use of machinery and applied science, while it diminishes the amount of manual labour for a given operation, may intensify the use of the land as a whole, and there are farms where mechanisation has so developed the land that it is carrying twice as many men as in the days when there was nothing but horse labour and hand harvesting.

Suppose we decide on a plan for agriculture, there is no doubt that it would have to begin by deciding not only what its aim is going to be, production or increased employment, but also what types of production are most required in the national interest. It would have to determine
the relative claims of live-stock and crops. It would have to take into
account that factor of which we are now becoming increasingly conscious,
the needs of nutrition of the people. We know that certain parts of our
population have been suffering from malnutrition and need, particularly,
milk and more fresh vegetables. Our agriculture ought to be shifted in
order to meet those requirements.

Take, for example, the silt lands round the Wash rivers and the Humber.
Those are the richest lands in the country, and are eminently suited for
the growing of crops required in the national interest, vegetables of all
descriptions. But as this soil will grow great crops of wheat, which
enjoys a subsidy from the Government, large areas are devoted to
wheat. If we had a national plan, there would be no wheat grown on such
land, which is much too good for that purpose. There is much land in the
Midlands where one can still see the old ridge and furrow which took their
shape in medieval times and have been preserved ever since. They were
corn land, and they could be corn land again under modern conditions.
With the applications of power which are possible we could really cultivate
that sort of land more cheaply, and to a depth which has never been stirred
as yet. Throughout the Midlands there is a great deal of land now growing
very second-rate grass which could profitably be put under the plough. A
good example of the kind of thing that can be done is to be seen near
Newark. Years ago a poorly farmed area of some 3,000 acres was taken
over by the Ministry of Agriculture of the time, and that indifferent grazing
land is now a wonderful crop-producing area.

Our planning has got to take all these considerations into account. We
are able to make options because we are not a self-supporting country and
we grow only a small proportion of the food we consume, perhaps two-
fifths. We must consider, too, the possible emergency of war. For this
purpose we require a very close survey of the country comparative in its
detail with the Land Utilisation Survey, because by the geological structure
of the country we are denied broad outcrops, the rapid succession of
strata over England from the north-west to the south-east, giving rise to
a succession of different soils. As every farmer knows, you may get rapid
variations in the soil as you move from field to field of a particular farm.
Our survey has to be very minute if we are to put the land to its best use.

If we are to think of the emergency of war we must get that land in use
now. It is no good saying that grassland is a great reserve of fertility when
war comes. It may be a great reserve of fertility, but it is locked up unless
the men and the machines, and the knowledge of how to work it, are already
on the spot. They cannot be improvised. That was the lesson of the
emergency campaign to put the land under the plough in the last war.
This second-rate land must be got ready, producing now, if it is to be
intensified in its production should the dreadful emergency of war arise
again.

There have been many allusions to mountainous land, with a high rain-
fall, in the west, much of which is rough grazing with little economic
value. That land can be made of agricultural value if it is wisely managed.
We know that the population is shrinking rapidly in the Highlands of
Scotland, in Cumbria and in Wales, but there are certain districts where it
is being preserved by townspeople who come out and bring a new source
of income to the small farmers there who let rooms to them during the three
summer months. There is one college, for instance, that is developing
land of that description by the simple process of adding to the ordinary
farmhouse reasonable accommodation for visitors, two or three rooms
with proper sanitary accommodation which can be let in the summer.
That little extra income to be derived from the visitors is just enough to turn the small holding in this mountainous country into a proposition on which men will willingly continue to live. And it is a wise provision for the townspeople, too, for these areas are the natural playgrounds of the towns. Let us facilitate it by all means. Even as an economic proposition it will pay to attract tourists to the Highlands, and, instead of trying by other means to exclude visitors, even to the extent of letting roads fall into disrepair and breaking down bridges, to attract people so as to help to save the population which is semi-dependent upon the tourist traffic.

We can see very easily how, if all this land of ours in Great Britain were under skilful management, under one hand, it could be put to much better use than it is at the present time; but all these reforms which have been suggested will never be realised until, in some way or another, the State owns all the agricultural land of the country.

Prof. J. H. Jones,1—'Planning' does not mean framing a measure or series of measures to meet an emergency; it is not a surgical operation or a bottle of medicine, but a mode of living which is appropriate to the stage of development already reached by human society. A 'plan' does not work for its own extinction; it contains a degree of continuity or permanence that is lacking in an emergency measure. It must, therefore, be carefully thought out, in all its bearings, some time before it can be put into operation; and it should be sufficiently flexible to be adapted to changes in the circumstances which it is designed to meet.

We cannot embark upon 'planning' without agreement about its purpose: we must first of all know what we want. But there may be agreement about the purpose without agreement about the method by which it is to be achieved. The purpose of planning may be economic (narrowly interpreted), social or strategic, or a mixture of all three.

In so far as a plan is conceived for the purpose of defence the economic purpose disappears. The choice between guns and butter, or between fats, flesh and cereals, may be real and pressing. Defence may be assumed to be necessary either against external aggression or against internal strife. Two million people placed on the land may mean not only a greater domestic supply of foodstuffs, but also two million fewer potential communists. Europe illustrates the fact that a national plan so conceived involves economic waste—a cost which is accepted. For defence remains more important than opulence.

Planning for a social purpose may likewise only be possible at an economic cost. Thus it may be regarded as desirable to prevent over-concentration of population even where economic forces tend to produce such a result. Industries may be guided—even forced—into geographic regions in which human costs of production are higher than in others. A declining industry, such as coal mining, may be so controlled as to prevent too rapid a decline in any one part. Economic factors are subordinated to the presumed need for assisting the inhabitants of depressed regions and perpetuating the existing distribution of population or reducing the rate of change.

There is a sense in which it is true to say that industry has always been the subject of planning; the method of selecting industries and of determining their location and method of operation being that of relying mainly upon individual initiative and enterprise directed by the prospect or chance of making a profit. But it should be added, first, that the economic purpose,

1 Prof. J. H. Jones was the seventh and last speaker and, the meeting having exceeded its time limit, he did not deliver the address of which the leading topics are here printed, but confined himself to a few remarks of general interest.
narrowly conceived, has not been pursued to the exclusion of all other considerations; that the method of selecting industries already described has not been followed in all cases, and that the system of competition has not been free from regulation.

In many industries competition is found to be self-eliminating; the quest for profits has led to the creation of monopoly. In extreme cases, such as local transport and the production of gas and electricity, that duplication of units of supply which is an integral part of competition is obviously wasteful. Such industries are known as technical monopolies, and are either owned and operated by public authorities or operated as public utilities. But even in other cases, in which the public advantages of monopoly control are not so obvious, and may be seriously questioned, monopolistic control has been substituted for competition. Moreover, such monopolies are now frequently called ‘plans’; monopoly control is regarded as a form of planning and approved (as in the case of steel) by public authorities. In some cases, for other reasons, the State has not merely approved a privately constructed monopoly, but even tried to institute monopoly control.

Within the large framework of competition the State has been ‘planning’ in the past. It has restricted competition for social reasons; it has fostered the growth of selected industries for the purpose of defence; it has controlled technical monopolies; it has favoured monopoly control in appropriate cases. Each case has been taken on its merits, in the national interest. This brings us back to the question, What, precisely, do we mean by planning? What purpose have we in view? Do we wish to build up a much larger agricultural industry, though the heavens fall? Do we wish to plan the land in such a way that national welfare is increased, even though such a plan mean the sacrifice of agriculture? Do we intend to assume world peace or perpetual danger of war? Do we desire the State to embark upon a new policy, with a new purpose, or merely to pursue its present policy of taking each case on its merits, with a presumption against direct interference and a further presumption in favour of efficiency? Before one can answer the question ‘Do you believe in a planned economy?’ one requires to know what is to be planned, and for what purpose and by what method.

We are often told that we live in a rapidly changing world, which calls for changes in the control of the economic system. Reference has been made again and again to the problem of the Special Areas, and to the Royal Commission that has been appointed to examine the larger problem of geographic trends in industry and population. We have heard much about the immobility of labour, the need to attract industries to depressed areas and thereby avoid the ‘social oncots’ involved in the development of new areas. The first step in planning is to examine the powers and responsibilities of the authorities that are likely to be called upon to administer such proposals. The first stage in planning is to ‘plan’ appropriate public authorities. And here we meet with the first practical difficulty involved in any scheme of planning on a large scale—the difficulty of centralisation.

We cannot handle human beings like pawns on a chessboard. For this reason a scheme which, on paper, may appear inferior to another may prove to be wiser, in practice, than the latter.

The third difficulty is that a new plan, however carefully it may be prepared, is usually found to be seriously defective when brought into operation. The result is that many see in its defects not those of the specific plan but those inherent in any plan. A reaction may set in which will prevent any extension of planning to spheres of activity in which it is equally necessary.
Finally, we have to remember that it is the habit of Governments to deal with problems only when they become urgent, though they may be careful to hide the fact that they are urgent.

These practical difficulties must be emphasised because scientists are apt to content themselves with stating what should be done without indicating how it should be done. We should be clear in our minds about the purpose that we have in view and the methods that we regard as not merely desirable but also practicable in the circumstances of the time. This involves research of a different character from that which has hitherto been regarded as within the scope of the existing Sections of the British Association.
The First
RADFORD MATHER LECTURE

BY
The Rt. Hon. J. RAMSAY MACDONALD, P.C., M.P., F.R.S.

ON
SCIENCE AND THE COMMUNITY.

(Delivered at the Royal Institution, Albemarle Street, London, on October 22, 1937.)

Mr. President, Ladies and Gentlemen—May I open by associating myself, if you will kindly allow me, with the words spoken by the President regarding Lord Rutherford. I knew him for a good many years as a personal friend, genial, happy, inspiring as a great teacher and as a very fine, high spirited public servant. Whenever I had to ask him as an officer of State for his help his feet ran swiftly to accede to my request.

I must begin by expressing two things that are upmost in my mind at this moment—the thanks we all owe to Mr. Radford Mather, the generous founder of these lectures, and the pleasure I feel at having been asked by the Council of the British Association to deliver the first of them. Mr. Radford Mather has been impressed by the importance of the work of the scientist in the everyday life of our people, especially at this moment; and after a long life enlivened by scientific and social interest, he feels keenly that the recognition of that work is not only owing to the scientific worker himself, but will be helpful in inducing the public to use the advantages which the scientist has put at its disposal.

The history of scientific discovery and the application of scientific knowledge to human activities in every field reads like a romance, and I can imagine no more interesting career for anyone whose tastes lie in that direction. The interest and importance of the scientific career, however, are not confined to the laboratory or the classroom, but should be regarded as a major, if indeed not the major, creative influence on this generation, which is undergoing such great changes of some of which we are not aware. In national economic well-being, especially in making high standards of living possible, in the evolution of both the powers and the forms of national institutions, in the efforts to create and secure social harmony and co-operation, the scientific method, if followed,

1 The President, Prof. Sir Edward Poulton, F.R.S., was in the Chair. Before speaking of the inauguration of these lectures, referring to their founder, Mr. G. Radford Mather (see note at end), and introducing the speaker, he had paid tribute to the Rt. Hon. Lord Rutherford, F.R.S., past president of the Association, who died on October 19.
would be of great assistance, and would save some futile experiments, mistaken agitation, and unworkable proposals. Thus, the politician as well as the professor, the housewife as well as the manager of great works, whether they are aware of it or not, depend in the performance of their work upon whether the public mind not only responds emotionally, but sets about making that response, with the same care as to facts and the same anxiety as to methods as the man of science shows in his own special field. What are called 'moving descriptions' of human ills, quite accurate as to facts but left without carefully worked out conclusions as to treatment, often become serious obstacles in the way of satisfactory remedies.

Perhaps the immediate reason why I have been asked to speak to-night is because it was my good fortune to have held the office, for the past year, of Lord President of the Council. This made me the constitutional head of the scientific work for which the Government is directly responsible, and brought me into direct contact with bodies like the Department of Scientific and Industrial Research, with the National Physical Laboratory as one of its main stations, the Medical Research Council, and the Agricultural Research Council, together with the co-operating bodies.

I found an inspiring companionship devoting its life and genius to find out how the potentialities of Nature, discovered and proved by research, could be valued, combined, and used by reason and further experiments, so that man may be a co-operator and partner with Nature's powers and rise above being a bond-slave; and that Nature herself may find her ways understood and made valuable, as quickly as possible, for meeting human needs.

In all public affairs I myself am an unrepentant evolutionist. There must be change, not for the sake of change, but because social harmony and progress will always continue to require it. Were it not so, civilisation itself would soon become a relic, and we should have to deal with a society which has breathed its last progressive breath and has reached the stage of disruption through evolution because it is not adapting itself to the new conditions which are the immediate offspring of its own life, a disruption not created by men's imagination, but by the evolution and the changes in the life of every society, every combination of human beings, every community that has not come to an end of itself. Civilisation is not a static state but one of dynamic activity which requires direction. The most lasting and fruitful of changes are those which arise from the failures of existing conditions or their hitherto imperfect successes. Or, we may put it in this way in full accordance with the truly scientific mind: creation was left imperfect for men to carry it on towards completion by coming to understand it, both as an accomplishment and a promise, and you cannot separate the accomplishment from the promise if the community is to live. The place where the shoe pinches either body or mind is the spot where disruptive unsettlement shows itself first. The remedy is not to curse the shoe nor to content ourselves by describing the pains. The shoe should be adapted so that it may be useful (as it was intended to be) without doing what it was never meant to do, rack us with pain.

Pain in the individual corresponds with discomfort and unrest in the community. Both are signals of harmful processes and call for study
and treatment in the scientific spirit, in order to prevent more serious results—serious illness and death in an individual, revolution and disruption in the community itself.

By the scientific method it might often be possible to prevent even the pain and unrest. This optimism in progress, however, assumes that an awakened interest in the work of the experimental scientist will incline the public to follow, in its own special concerns, the methods and spirit of the scientist himself. I make no plea for the scientist as statesman. He will not be likely to be any better than Plato’s philosopher. The plea I make is for a practical Democracy, but if Democracy is to triumph in the attack now being made upon it, it must have a method, and I believe that the methods of the scientific worker and the way he sets about his work will clarify and steady the popular mind not only to complain eloquently but to conclude wisely. I think that that conclusion stands out boldly and baldly in the mind of everybody who has been following scientific work and scientific discovery during the last ten or fifteen years.

In these days, when science is renewing its claims to be regarded as an essential part of cultural education and to rank in value with the humanities for that purpose, it must be able to show that its pursuit is not only to discover facts but to influence values of life as well, and that it can not only put power into men’s hands, but quicken the human qualities of mind which take care that that power is used for human well-being and progress, as I am afraid it is too often not regarded at this moment. The scientist as citizen should take a lively concern in the way his discoveries are used. Professor Lancelot Hogben contributed a lively thought-provoking paper to the Blackpool meeting in which he emphasised this dictum: ‘The cultural claims of science rest on the social fact that the use and misuse of science immediately affects the everyday life of every citizen in a modern community.’

If at the end of a generation the most advertised contribution that scientific activity, particularly in physics and engineering, has made to the life of the community, is that it has produced power of destruction which can be used to appal the most indifferent to human suffering and injustice, the labours of the scientist of our time run the risk of being permanently deplored. This, I am glad to say, is now being widely recognised by scientists themselves. On the other hand, as I am urging, the part which our present scientific research can play in social well-being and solidarity depends upon an instructed popular view of the value and significance of those researches and their uses as a whole.

Let me, therefore, enforce what I have said by reminding you of some subjects and directions in which scientific investigation has been active, in recent years, to prove that it has not only contributed to our knowledge, but has been important in helping us to understand how to begin to settle the problems with which every progressive community has to deal to-day.

Let me refer first of all to a question, the most fundamental of our concerns as a community and as individuals, which, after years of patient research and experimental work, is occupying a more and more important place in the public mind. The vital problem of nourishment and public health has been quickened with new energy by the work of the scientific investigators, and I am glad to say that the attack upon it is being prepared
by a combination of the scientific and research workers in co-operation with men of affairs. Who can say what changes are to follow upon such a combination backed by close and practical application of an instructed popular interest in nourishment? Let me glance at some definite results which may well follow. The discovery of the satisfactory menu is one thing, the provision and use of it is another. The first result will be that we ask ourselves how agriculture is to adapt itself to the demands which vitamins, for instance, make upon it because the nourishment upon the table must depend on what is supplied by the field. I think that that is a good scientific conclusion. On that may follow a study of some new problems in the machinery of those necessary marketing schemes with which we have been experimenting for some years; the question of prices will have to be examined with a new meaning and urgency, especially retail prices, for, as it happens, the most valuable foods in the new régime of nourishment are also the most expensive; the expansion of consumption following that of production will have to be dealt with in new lights and from new angles in accordance with scientific methods; our domestic arrangements should also be affected, for the function of the housekeeper should now have new interests and responsibilities which will endow it with new dignity and importance, so that it will be regarded as of higher value, rather than little, if anything, more than mechanical drudgery throughout a long day, as it is too often regarded at this moment.

I lay emphasis upon this last point, for, to me, it is of supreme importance. The care of the family will thus be regarded as of the greatest importance in the life of the community, and its income and expenditure will be considered with more concern by the public. There is good evidence that children now being brought up in many Poor Law institutions are better fed, and therefore have better physical development and health, than corresponding children in private homes living with their parents. This is a serious reflection, for it would be pathetic if it became possible, and this is by no means mere phantasy, in later years to pick out for special approval those brought up under Poor Law conditions from those brought up at home. I cannot imagine anything more deplorable than that, from the point of view of community health and community well-being. A formidable barrier to the deterioration of family life, which is becoming one of the most disturbing tendencies in modern social evolution, would be thus erected. Be that as it may, however, the scientific investigations into nourishment, as has been plainly pointed out in the last Report of the Mixed Committee appointed by the League of Nations to study Nutrition, should bear rich fruits. The report I have in mind is called 'The Relation of Nutrition to Health, Agriculture, and Economic Policy.' All this research has led to the widening of our conception of public health, and has tended to raise the value which the community places on the fitness of the human body.

I must further point out, however, that already so effective has been the work done by various scientific workers that the problem of nutrition has advanced through two well-marked stages. The first is illustrated by the public-spirited labours of Mr. Seebohm Rowntree and his followers who roused a widespread interest in the question of diet. They based their contentions upon the simple fact
that the human body required a certain amount of calories to supply bodily needs and energy for muscular wear, and of proteins to replace ‘wear and tear,’ and in the young to provide for growth. Up to almost yesterday medical training in general health has been ruled by this view.

I have been assured by competent authorities that now there is no ‘starvation’—I emphasise that word and draw your attention to it—in Great Britain in the sense used by Mr. Seebohm Rowntree when he made his investigations on the dietary of the working classes. Nearly all people, I am told, now get sufficient calories and protein.

But another and more penetrating group of scientific workers, whose leader in this country is Sir Frederick Gowland Hopkins, have by their investigations, strongly supported by the Medical Research Council, helped to discover the significance of vitamins and mineral salts in food, and have changed fundamentally the question of nutrition in relation to health.

In relation to these discoveries in the essentials of nutrition our shortcomings are considerable. Very many people do not get sufficient mineral salts and vitamins in their food.

In quite another and most specific direction these more recent discoveries regarding food should lead directly to changes which will open up great opportunities for a healthier life for the mass of our people.

There is now a common belief that, as regards the quality of our population, we ought to contrive to have a considerable increase in our people now living directly on the soil, and I believe that our present distresses should be used, in every possible economically sound way, to advance that object. As a result of these researches, and in continued consultation with science, this can be done. The application of the vitamin doctrine to agricultural problems is bound to give a great impetus to the cultivation of protective foods—especially fruit, milk, dairy products, eggs and vegetables—possibly on allotments based on the practice of co-operative cultivation, purchasing and marketing. The worker on the land would then find himself in a new position. An extended market would be open at his own door for the rich vitamin fruits of his cultivation. This is necessary, for he may produce, but if he has no market he will starve. These things necessarily follow upon our scientific investigation into food. The provision of agricultural work is necessary if we are to keep a country population, and the maintenance of that population is essential to our existence.

But these investigations are also giving a wider and richer meaning to health. At this point I must refer to the Medical Research Council. The work of our Medical Research Council cannot be overlooked even in the briefest and most general survey of the relations between Science and the community.

We have seen both medical and surgical treatment revolutionised during the last fifty years—many diseases hitherto fatal can now be treated and the patient restored to health; other deadly and disabling diseases have disappeared from our midst. Lack of knowledge is still, however, the main limiting factor in the fight against the many diseases which remain, and only continuous and laborious research will lead to success in their control. In this fight the organisation of the Medical
Research Council is playing the leading part as far as Great Britain is concerned. Its success in researches centring round such problems as nutrition and virus disease are of world-wide repute.

Recently during my tenure of office as Lord President I was glad to be able to assist the Medical Research Council in obtaining a substantial addition to its grant in order to promote the building up of a department in CHEMOTHERAPY. Chemotherapy is the preparation and use of drugs built up in the laboratory (as opposed to natural products found in plants and animals) which by experiment are found to have specific curative effects on certain diseases. We know that up to the present, most of this type of experiment has been in the hands of the Germans. On a number of occasions British workers have made a key discovery in the science, but, lacking any effective backing for pursuing the subject, have had to stand by and see it developed by their German colleagues. With the new Institution now to be set up it can with reason be hoped that British chemists and medical scientists will be able by their combined efforts to forward this promising field of discovery and so help in the alleviation of much human and animal suffering and loss.

Health will now be seen more and more clearly to depend upon the body being properly nourished to resist disease. But health means more than a successful control of disease. Health is a quality of life. Health means the harmonious working of the physical organs of the body with each other and with the body itself as a whole. In perfect health, the energies of the body will respond to every duty which a man in society has to meet, for it will mean and depend upon the harmony of man with himself, his circumstances and his ideals. Social duty is much more easily followed by a community of men and women robust in health, than by one which is weak in mind and body. It is this unity in the life of the human body, the physical body, mind, and soul, which is health.

Be it observed that this change for which those recent activities of science compel me to hope, and challenge me to work, can only come when the sciences dealing with life have been enlisted to play their parts in bringing it about—from biology (one of the most neglected of the sciences in its political, its communal and its health applications), all along the front to psychology and ethics. Scientific work in recent years is moving us, I am glad to say, nearer and nearer to that united front.

Now let me glance in another direction at some more definite activities of the scientific investigator with a direct bearing upon the industry upon which the economic life of a community depends. Production and trade supply the life blood of society. There can be no State, well organised to maintain a high standard of life for its people, if its blood-currents become stagnant and thin.

The War brought about a great change in the realisation in this country of the importance of science, a realisation which found expression, in 1915, when the Government of the day set up a Committee of the Privy Council to concern itself with Scientific and Industrial Research. This step marked the first comprehensive and organised measure taken in this country to help industry generally through the application of Science. The Department of Scientific and Industrial Research was established soon afterwards to operate the decisions of the Committee of the Privy
Council, and one of its earliest acts was to set on foot a scheme to encourage our industries to co-operate with each other and create scientific research organisations for the benefit directly of themselves and ultimately of the nation as a whole. Although the Government contributed to the funds of these organisations, called Research Associations, in proportion to the amount subscribed by industry, the Associations were to be—and are—autonomous bodies controlled by their respective industries. Apart from its interest in these co-operative organisations, the Department of Scientific and Industrial Research has directly under its control a number of laboratories which are prepared to consider problems submitted to them by firms and to give assistance therein on the payment of fees for services rendered.

The stimulus thus given to industry and the information supplied have been of the greatest national value, especially as regards international markets; and there can be no doubt that when the Government was able to restore national credit and confidence, the work of the scientific investigator played a great part in the national recovery, and, in consequence, in placing thousands of workpeople in employment. This could never have been done except on a foundation of an increased national wealth and an improvement in national production. Much of that has been due to the scientific worker.

Standards of life have undoubtedly been raised and opportunities for improving wages provided, whilst leisure has been extended and the conditions under which people work, even in spite of some serious shortcomings, greatly improved. Human stress and strain has become a consideration in work, and the adaptability of the individual to employment has greatly eased the discomforts and disappointments of the worker. These tendencies have by no means exhausted themselves, and an enlightened determination to maintain the conditions of uninterrupted consumption of products by increasing the share of the worker in the augmented product will minimise the hardships of any slackening, at present uncontrollable, in the market demands for production and labour. Here I lean upon science to find out how that can be done.

The needs dealt with by these scientific investigations cover an extraordinarily wide field indicated with interesting clarity in the Annual Reports of the Scientific and Industrial Research Department, and its organisations such as the National Physical Laboratory. From these it is seen that organised research extends apace, and that the co-operation between scientists and industrialists has become a well-marked feature in our industrial life. Industry is no longer satisfied with sporadic consultations with science. This has led, as the last Annual Report of the Department of Scientific and Industrial Research records, to a steady improvement of the efficiency of our industry and the comforts of our working staffs.

I mention one or two other items showing the industrial activities of the scientific worker. But first of all, I cannot help referring to the use made of the William Froude Tank for testing shipping designs. No separate item of work done by scientific experiment applied to industrial needs has interested me more than the use made of this tank. I quote from The National Physical Laboratory Report for 1931 (p. 290):
Among the results obtained by comprehensive researches in the tank which have been adopted in the industry are the introduction of the "cruiser stern" on ordinary mercantile vessels, the introduction of "aerofoil" types of marine propellers, the change of raked now common in single screw ships, and the use of a central fin on the later ships to control inflow into the propeller. Further as a direct result of researches on cargo ship form, commenced at the William Froude Laboratory in 1911 and carried on more or less continuously, the resistance to motion of a "good" ship form has been reduced by about 10 per cent. The effect of this can be appreciated from the following figures. The total tonnage of vessels classed at Lloyds at 30th June, 1930, owned by Great Britain and Ireland, was 15,000,000. Taking this at £1,0 a ton it amounts to £150,000,000. A saving of 10 per cent. on the coal bill means an average saving alone of £4,500,000 per annum. In particular instances of the research carried out on the lines of a particular ship (many such researches are made yearly) reductions sometimes reaching 35 per cent. are achieved.

It is interesting also to note that in the corresponding report for 1936 (p. 7) it is stated that:

'"The importance of the work carried out by the William Froude Laboratory is exemplified by the fact that of the 1,180,000 tons of merchant shipping listed as "under construction" in Great Britain during 1936, no less than 920,000 tons were based on the Laboratory tests.'

And now I think of the advances made in the production of electric lamps and lighting, the vastly improved position of this country in high-definition television, the development on a commercial scale of the huge plant for converting coal into oil by hydrogenation, the marked growth of the plastics industry, and many other important advances. And, I repeat, we are only beginning this intimate co-operation between Science and Industry, between the genius of the scientist and the practical needs of the industrialist—worker as well as manager being engaged in it. Nor is the advance only in the needs of highly organised technical industries. So let me add a few more illustrations of the kind of improvements at this moment being studied and brought to a conclusion.

I find that research is being actively pursued into the manufacture of shoes from the hides until the article is sold to the public; the building of soundproof and fireproof homes with controllable room-temperatures; the elimination of the squeaking of brakes and the drumming of panels in motor cars and road vehicles for popular use; industrial diseases, like the devastating silicosis; preservation and transport of fresh food like fish, eggs and fruits; the treatment of teeth—one of the most grievous of our common ills; fresh and good water. All very humdrum and small, you perhaps may say, but, as a matter of fact, taken all together, they make up a fascinating study in the irritating ills which deprive the lives of the mass of our people of the comforts which freshen the springs of human happiness and make possible the enjoyment of our national wealth and our social unity of spirit. Some of this work is not new, but all of it has received revived energy from those Departments which I have principally in mind this afternoon.

Investigation—I repeat it, it is so important—which ends innumerable irritating distracting and unnecessary noises, even if people imagine they
are not heard, the petty physical jars and discomforts of life, will confer the greatest blessing on the modern community in health and peace of mind and enrich the quality of life itself.

Here I submit a warning. I recently had to exchange views with an admirably inspired friend on a disease in which he was keenly interested. He was in a hurry for results of the investigation which I was able to assure him from my own knowledge had already been begun by the Medical Research Department. A scientific inquiry into the causes and treatment of the simplest malady entails experiments the results of which cannot as a rule be forced. A trustworthy scientific conclusion requires time to build up. This is caused neither by the laziness nor the indifference of the man of science, but by the nature of his task, and, if anyone is to be blamed for delay and uncertainty, it is the Creator himself. Experiments fail as well as succeed, and the work has too often to be begun all over again. The story of some of the apparently simplest discoveries of science is often as marvellously complex as, say, the life history of the eel.

Not only have great firms extended and developed their own research establishments, but many of the leaders of industry have given lavishly of their time and thought to the formation of the Research Associations to which I have referred.

This afternoon, I must limit both the length and the width of my excursion into those fields whither modern scientific discoveries are leading us. Some of the most important have been interestingly dealt with in papers read at recent meetings of the Association. They also find a place in some most challenging articles in recent issues of the scientific press. Nor will scientists fail to observe the meaning of that most significant resolution passed by the recent Trade Union Congress agreeing to a Committee of Scientists with whom Congress can consult on policy, outlook and methods of handling their special work. Thus not only is a scientific front being created to encourage scientific inquiry, but it is receiving the co-operation of all classes and interests, in applying its discoveries to advance communal well-being.

Although I have devoted much of my time to the work of the Government departments concerned in the development of that scientific knowledge which applies to industry and health, I should be loth to give the impression that I do not appreciate the research of other well-known public bodies and institutions, and the public service rendered by work done in other scientific territories—chemistry in all its many-sidedness, for instance. I have been thinking to-day mostly of the laboratories I have so frequently visited. But they are only a corner of the scientific life of our day.

Applied science is nearly always based on academic discoveries and such discoveries are often made in Universities where research is generally pursued without any view to results of practical application. Everyone must be keenly conscious of the fine achievements in scientific research of our Universities. It is literally impossible, for instance, to exaggerate the consequences on modern life of the work on the constitution of the atom pioneered and directed by our late friend, Lord Rutherford, whose parting from us moves us all with sorrow.

Before I conclude, I must refer to certain aspects of applied science,
though it must be briefly and more by way of putting some thoughts into your minds, than by discussing them fully with you.

Further investigation by the scientist is not universally welcomed. The reason is that physical science and machinery mean pretty much the same thing in the public mind, and two accusations are made against machinery which are in very many minds as they see what wonderful things science has done in recent years.

But first of all there is the general doubt whether this machine age has brought us on the balance any benefit, and is anything more than an unfortunate by-road in world history. It is argued that, in pursuing the machine, man has lost his soul and those qualities which proved that he had a soul. That great question in æsthetics cannot be dealt with in this lecture, even as a side-issue. I believe, however, that a very large part of the case for doubt is based upon the misuse of certain applications of scientific discovery for which the man of science cannot be blamed and ought not to be blamed. But, further than that, I am not at all sure but that the proper use directed by such intelligence of science will be found to provide the antidote—conditions of leisure and culture which will enable us to rediscover the qualities of life which modern society is said to have lost. It is worth thinking about.

But there are two doubtful thoughts of immediate importance which I must notice, if for no other reason than to show that my great admiration has not been reached by shutting my eyes to anything that has been said on the other side. The position indicated in the sentence I quoted from Professor Lancelot Hogben is in my mind.

Much of the new machinery appears to displace labour and so create a new source of unemployment supply. This is shown dramatically in agriculture. I saw it during this summer. At hoeing time the fields are occupied by labour as before; at reaping time the field, crowded fifty years ago, by lively men and women singing happy songs and dressed so as to be bright points for catching and reflecting the warm unclouded sun, are now empty and silent save for the reaping machine and its rattle. And it is said that every industry where machinery can be profitably introduced tells the same tale. Therefore in many quarters science is regarded as the enemy of human beings who desire to live as self-supporting workers. So has it always been at times of great change: that allegation has always been made in industrial production. A reply may be made which reminds us of the experiences of labour in history, that the displacement of men by machinery has always been but temporary, and that with an increase in national wealth we also have an increase in the national demand for labour. There is some evidence that that experience is being repeated to-day. It is, however, rather unconvincing to the man who actually finds himself unemployed because a machine more efficient than himself as a producer has taken his place in mind and factory. Be that as it may, machinery which takes the place of the hard, uninspiring and deadening drudgery of human beings is all to the good, and that which multiplies the efficiency of human skill is also to the good. I look, however—I have already said and I repeat it—to the more direct benefits, and do not see why they should not be obtained mainly from an increase in leisure, the enjoyment and use of which are amongst the most pressing
of social problems to-day. And there is another pressing problem in front of us—how to reduce cost of production without lowering standards of life. Scientific invention properly used, I believe, will give us the best chance to solve both problems.

The other trouble is kept fresh and urgent by what we read every day in our newspapers of the great advance due to science in the destructive forces of the world, as shown in China and Spain, and to be repeated with increased horror wherever war breaks out. If we cannot avoid war, we cannot avoid the very worst that can happen in warfare. But this raises issues which depend upon other considerations than those of the field of science. Science increases power which can be applied both to life and death. Science cannot help the men who have made air forces possible, for instance. They have also created civil air fleets, and I consider that a great benefit, and if the communities cannot make and keep peace, or if they are so blind as to follow the aggressive actions of their rulers, democratic or dictatorial, the responsibility is theirs. If peace is not secured by, say, diplomacy, and the will not of one but of all nations to keep peace, it is both a false judgment and a very cowardly one to blame the scientific engineer and worker. The action of the farmer in growing corn and food for war is exactly of the same kind as the engineer who makes flying engines. Peace or war are not the responsibilities of scientists as scientists, except in very special cases, so long (and it will always be) as the discoveries which increase our peaceful and beneficial resources can be used for war machinery.

At the same time, there is a feeling among many scientists that the ease with which their labours may be misused in this way should make them, as citizens, active in creating and upholding the public opinion of the nations to which they belong, interested in protecting their work from being abused, as beneficial poisons and many chemicals essential to peaceful industry can be.

I have presided over a fair number of International Conferences—your own people being represented—of chemists, engineers and others interested in this question, and one and all gave a hearty response to every mention of this interest and duty of theirs. Scientists will also remember that from that distinguished body, the Royal Academy of Sciences at Amsterdam, came a resolution which was discussed and improved at the Third General Assembly of the International Council of Scientific Unions and published in two issues of Nature of April 24 and May 22 last. It recognised the social responsibilities of science and scientific workers, and the Assembly decided to have the question closely considered.

This misuse of scientific discovery is the concern of the political organisation of citizens, including scientists. In any event, we ought to be careful not to go upon altogether false scents, or set up issues which are too narrow to end the ills from which we suffer. We can go back to bows and arrows but that will not remove the grievances of nations for which they will fight, nor supply the enlightened diplomacy which can keep the peace without injury to a nation’s sense of injustice. Do not let us be misled by thinking that the scientists as such can stop or cause war. The military leader can use the triumphs of science as he likes to horrify us with warfare. That is all.
In any event, Science cannot cease to follow the exhortation of Carlyle to 'produce in God’s name,' and it would be bad for humanity generally, if it tried. It is not scientific to deal with the offshoots of evil. The scientific method goes to their roots. Let us face our present conditions in the historical and biological spirit, and much progress in the science and art of applying scientific knowledge, in the scientific spirit, to society and government, can be recorded.

It must be evident to everyone who has thought about the social consequences of advances in scientific research that they call for a reinvigoration of social science. The experiences of later years points out the urgent desirability for close co-operation between the scientist, the industrialist, and the man of affairs, to enrich the lives of human beings, to help such changes as will diminish the disruptive forces in society, and to promote social solidarity which lies at the root of human progress and happiness. And this can be done. It is, indeed, the next step, made not only possible but inevitable by the great contribution to scientific progress made in recent years by scientific research.

NOTE.

Mr. George Radford Mather, a life member of the British Association, to whose generosity the Association owes the foundation of the Radford Mather Lecture, is a retired engineer, now living at Wellingborough. In 1909, fifty years after his apprenticeship, Mr. Mather retired from active business, and since then he has devoted much time and energy to the study of those minimal surface relations exhibited, for example, in the spherical shape assumed by a small raindrop. It was during a correspondence on such matters that attention was directed to the increasing interest shown by the Association in the social implications of advances in science, a subject about which Mr. Mather is seriously concerned. Deeming that this aspect of the Association's activities is one to be encouraged, Mr. Mather has provided funds wherewith to endow a lecture, to be called the Radford Mather Lecture, to be delivered triennially in London or the provinces, and generally to be concerned with the effect of advances in science or communal well-being.

It is a matter for regret rather than surprise that the venerable founder of the Lecture—he was born at Irchester so long ago as 1841—was unable to be present in person and to hear the late Mr. Ramsay MacDonald’s thought-provoking address. Fortunately his son, Mr. C. J. Mather, was able to attend and to convey to Mr. Radford Mather the thanks and good wishes of the Association.
BEGINNINGS OF TOWN-LIFE IN BRITAIN.

By Dr. R. E. M. Wheeler.


The foundation of town-life in Britain has been ascribed to the Romans. The Celts are regarded as essentially a mobile country-folk, with a fluid, non-localised system of administration that is epitomised for the modern mind in the organisation of the Highland clan. ‘The Germans and English,’ wrote Haverfield, of the pre-Roman populations, ‘occupied villages. . . . They dwelt scattered up and down the land. . . . The appearance of town-life among any of them is a sign from the south.’ And a generation later, the most eminent of Haverfield’s pupils and successors has recently affirmed that the ‘hut-clusters’ which in part represent for us the pre-Roman settlements of Britain ‘were in no sense the nuclei and symbols of British civilization; they were not so much cities as slums. To convert Britain into a province of the Roman empire was to civilize it in the most literal sense of the word: to furnish it [for the first time] with towns.’

The purpose of the present lecture is to test these assertions in the light of advancing knowledge and to check our estimate of the Roman contribution to British urbanisation—matters of fundamental historical importance, in which nevertheless the determining factor is archaeology rather than history.

On the historical side the familiar evidence may be re-stated shortly. To Julius Cæsar, who knew only a part of south-eastern Britain, a British ‘city’ was a clearance in the woodland, fortified by rampart and ditch and used as a place of refuge both for men and for animals in emergency. For the rest, Cæsar adds nothing to our picture of the native settlements of Kent or Hertfordshire in his time. Archaeological exploration of the last few years at sites such as Wheathampstead, St. Albans and Colchester has, however, supplied further details. These cities were of large size. Wheathampstead, the earliest of them and possibly itself the ‘oppidum Cassivellauni’ stormed by Cæsar in 54 B.C., was nearly 100 acres in extent and strongly entrenched. The adjacent countryside was delimited by boundary dykes which would also assist in the protection of flocks and herds in time of unrest. And, not least, the situation of these towns in the immediate vicinity of river-fords and cross-country routes indicates
an interdependence and coherence amongst them which lifts them out of the parochialism of a mere peasant kraal.

But it is on the downs of Wessex and amongst the foot-hills of the Welsh border, in a country unknown to Cesar, that the most obvious and dramatic vestiges of our pre-Roman communities have survived; and here too—in Wiltshire, Hampshire, Dorset, Devon, Gloucestershire and elsewhere—exploration has proceeded at an unprecedented pace in recent years. This is not the context for a detailed discussion of these investigations. It will suffice to observe the number of the sites and to glance at certain characteristic features of them. Between central Hampshire and eastern Devon alone there are still upwards of seventy Iron Age fortified settlements, of which half at least are of considerable size relative to the population of the period. Many of them were permanently occupied, with houses and streets, sheltered by massive lines of rampart and ditch, the construction of which implies no small degree of wealth and authority and skill. What are now merely turf-grown mounds are known to have had originally the dignity of timber or masonry revetment; the summits of the main ramparts were, in some cases at least, reinforced fighting-platforms, and towers or built strong-points rose here and there amongst the outworks, that the slingers, who formed the principal fighting force, might control the approaches. The monumental Maiden Castle of Dorset, for instance, stood like some provincial Mycenaean of the downs—lands, appropriately known to Ptolemy's informants, it seems, as *Dunium*, The Dun or The City, without further particularisation. Its great earthworks must have been erected by large gangs or corvées, whose members sometimes died at their work, for their bodies were thrown here and there into the ramparts during the actual work of construction. In its prime, in the first century B.C., this famous hill-town is now known, as the result of excavation, to have contained great numbers of circular huts, with a multitude of storage-pits cut to a beehive shape in the chalk or built sometimes of unmortared masonry. The huts themselves were usually of timber and thatch, but occasionally had walls of chalk and flint rubble. They were approached from streets worn hollow with traffic and metalled and re-metalled with flint pebbles—in one case, with the addition of a well-built kerb of imported limestones. The roads passing through the entrances are deeply grooved with prehistoric cartwheels, the gauge of which, between 4\(\frac{1}{2}\) feet and 5 feet, approximated to the modern standard. Beneath the turf everywhere indeed are vivid vestiges of a busy, crowded scene, with much coming and going, and evidence too, within the limits of a generally primitive society, of not a little civic control and solicitude. And what may be said of Maiden Castle may be said in commensurate degree of other surviving works of the kind—Hod Hill or Eggardun, for example, both in the same county, the former with prehistoric street-lines still visible amongst its multitude of hut sites. By virtue of the permanence of their defensive architecture, the relative extent of their population and the administrative centralisation which they imply, the larger of these works can only be designated 'towns' or 'cities' in a true sense of the term. The Romans normally applied to them the word *oppidum*, a word whereby Cicero could refer to Antioch or Livy to Rome itself.
In the light of these new or newly verified facts, it is difficult now to deprive the Celtic inhabitants of lowland Britain of the rights of citizenship. Whether by modern standards these cities were or were not ‘slums’ is unimportant. It cannot be denied that the British lowlanders of the first century B.C. were organised extensively in civic units: citizenship was no innovation in Roman Britain. But let not this modification of the traditional view be pressed too far. One important element of the fully developed civic life of the classical world was absent or merely incipient in the life of these downland cities: namely, commerce. The almost endless cultural variety which marks British Iron Age settlements of the kind reflects their essential parochialism. Their economic basis was agricultural. Their economic outlook was defined almost entirely by the productivity of a given tract of countryside in relation to a limited agricultural equipment. If I may again cite Maiden Castle, I would emphasise how few of the many hundreds of objects found there during four years’ intensive exploration are likely to have been brought from far afield. Stone, iron, clay, bone, horn were all to be found within four miles of the site. Bronze or its components would have, it is true, to be imported into the region, but bronze was sparingly used. Two coral beads merely emphasise the extreme rarity of ‘luxury’ imports. Nor is the explanation far to seek. The tracts of naturally open country in which the Iron Age population was nucleated produced, as a rule, little that was of export value. There was little or nothing wherewith to balance an import trade. The downland citizens lived mainly by ‘taking in each other’s washing.’ Movements of population from overseas, dynastic ambition and other disturbing accidents broke their routine from time to time, but neither caravans nor argosies linked them permanently with worlds beyond the horizon.

This conclusion may seem at first sight to be at variance with the statement of Strabo, at the beginning of the present era, that Britain exported corn, cattle, gold, silver, iron, skins, slaves and hunting-dogs—a statement modified indeed by the same writer when he refers also to the meanness and small worth of the British exports. This export trade was doubtless confined mainly to the Belgic states of the south-east, whose cities, as indicated above, are in fact related to traffic-lines to a degree not apparent in the downland oppida of the west. Its importance is that it linked south-eastern Britain, however vaguely, with Roman Gaul or even Italy, and so prepared the way for that Roman occupation which, as we would now claim, may more fairly be said to have remodelled than to have created the urban life of the British lowland.

The modernity of the general lay-out of Roman Britain is familiar. Backed by an imperial treasury and a central authority, the Roman engineers arterialised the new province with a simplicity and directness that have retained their influence even into an industrial era which could not be foreseen. When not merely ancient cities such as London, Leicester, Winchester and York, but even essentially modern growths such as Manchester and Wigan are found to be in direct contact with Roman Britain, it is easy to stress the almost uncanny vision of the Roman surveyor. And in detail the astonishingly modern features of a Romano-British town are sufficiently familiar: the well-drained streets, the number
and elaboration of the bath-suites, the systems of central heating, the
dust-proof floors, the glazed windows, the simple but stately provision
for secular and sacred ceremonial, and a hundred other features which
combine in some sense to bring Roman Britain nearer than medieval
England to twentieth-century civic standards. The 'Romanisation of
Roman Britain' has been emphasised and, in due proportion, rightly
emphasised ever since Haverfield began his studies. In the present
context attention is directed, however, to the other side of the picture—
to the background which this brilliant show of modernity may easily and
unduly overshadow.

For the elaborate urban organisation of Roman Britain substantially
failed on test. It provided a pattern of civic life from which the medieval
Englishman was later to fashion a new Britain for himself from his own
homespun. But the progress of Romano-British researches in recent
years, at Wroxeter, Verulamium and elsewhere, has shown us more
clearly than we could see before both how Roman Britain failed in this
essential feature, and why. In the south, at any rate, the story unfolds
itself in this fashion. The Roman armies of invasion in A.D. 43
swarmed across lowland Britain, much as their successors swarmed
recently across Abyssinia. Native towns which resisted were stormed
dismantled: at Maiden Castle, for example, the dead, slain by
Roman swords and arrows, lay hastily buried outside the eastern gate,
and the gateway itself had been violently wrecked at the same period.
Such incidents would be easy to visualise, even in the absence of evidence.
But recent exploration has added significantly to the story. At Maiden
Castle, and doubtless elsewhere, the native population was not at once
displaced from its hill city. Over the wreck of the dismantled gateway
a new road was built into the town, and remained in use for some twenty
years. Nor indeed was any other course immediately feasible. To have
evicted the native townsfolk from their homes would have been to create
a huge and dangerous vagabond-population which would hopelessly have
impoverished the country and have brought endless embarrassment upon
the invader. Disarmed and left in their demilitarised towns, the natives
were sufficiently shepherded by an occasional police-post such as that
which can still be seen within a corner of the pre-Roman hill town on
Hod Hill in Dorset. Meanwhile on the one hand the conquest could
proceed according to plan, and on the other hand the complex task of
'building up' the new province behind the military zone could be under-
taken with the requisite deliberation.

This work of construction took time; Roman Britain was not built in
a day. Foreign capital had to be attracted into it, by optimistic stories of
its wealth in 'gold, silver and other metals' which Tacitus names as the
'reward of victory.' Foreign craftsmen had to revolutionise the homely
architecture of the native; foreign business methods had to be naturalised.
All this took time. It was not indeed until the golden era of Hadrian
and the Antonines that the Roman towns of Britain were made really
shipshape, and then only, it may be inferred, by large grants-in-aid
from the imperial treasury. By the middle of the second century cities
such as London, with its three miles of massive wall and rampart, or
Verulamium with its two miles of wall and its monumental gateways,
shone brightly on the provincial landscape. Little more than a century later the bubble had burst. The towns—if Verulamium and Wroxeter be taken as fair samples—lay in a state of semi-ruin. The town-walls of Verulamium were crumbling in decay, and carts passed carelessly over the fallen columns of the Wroxeter market-place. The reorganisation of the Empire under Diocletian and his colleagues brought to some cities a momentary respite: at Verulamium houses were rebuilt, the municipal theatre was raised from its ruins and (significantly, perhaps) enlarged. But before the end of the fourth century the city was once more in decay. Many of its remoter houses were no longer occupied, save partially and intermittently by squatters. The city had degenerated into a concentrated slum. How had this come about?

In part, the adversities which afflicted the cities of Roman Britain were universal throughout the Empire. They were aggravated, however, by local conditions. Successful town-life such as was contemplated in the design of the Romano-British cities implies the creation of a considerable and prosperous middle class. Such a class subsists on commerce and industry; and that is where the Romanisation of British town-life failed. The time was not yet ripe for so drastic a revolution. In pre-Roman Iron Age Britain, save to a limited degree in the south-east, there had, as we have seen, been no significant development of commerce outside circumscribed tribal units or complexes. Consequently, the extensive remains of Iron Age urban life exhibit no hint of what we should to-day call a bourgeoisie. Whether he lived in a capital city such as Maiden Castle or in some obscure hamlet, the house and furniture of the Iron Age householder scarcely varied in quality; an individual here and there might be marked by the possession of finer gear or some object of virtue, but there is no hint of a substantive middle class distinguishable economically from classes above and below. Such distinctions as existed would appear to have been based rather on tribal grade than on personal wealth. Upon this simple social system, the Roman régime attempted to impose the differentiations and responsibilities of a developed commercialism. Artificially reinforced, this foreign system seemed for a moment or two to achieve some degree of success. But it was insecurely founded; it lived on capital and collapsed in bankruptcy. Nor are the reasons far to seek.

Briefly, at no time was the productivity of the Roman province increased to an extent commensurate with the cost of a huge garrison and the whole paraphernalia of an imposed and radically foreign civilisation. True, lead-mines, iron-mines, even occasional gold-mines were opened up here and there, and must be supposed to have produced some small revenue. Other industries were established, but mostly of a local and trifling character, insufficient to return interest on the capital invested in the province by the city-builders of the spacious days of Hadrian and the Antonines. Soon after the end of the second century the trade in one of the most popular of imports, the bright red terra sigillata, was dwindling to vanishing point, and whole factories were, for this and parallel reasons, closing down in Gaul and the Rhineland. Rome had effected a political and social revolution in Britain without achieving the necessary counterpart, a commensurate economic revolution. Basically the
province was agricultural, and Romano-British agriculture remained essentially pre-Roman in its equipment and environment. Therein lies the crux of the problem.

Much play has been made of the sending of British grain-ships to the Rhine at a moment of emergency in the fourth century, but there is no evidence that Romano-British agriculture produced any great surplus for export. Coulters from the developed wheel-plough have been found at Silchester and (long ago) on the site of a villa in Gloucestershire, but we have no reason to infer that the heavy, fertile clay lands were brought appreciably into cultivation during the Roman period. We shall never know the extent or detailed nature of the lands tilled in the vicinity of the great Romano-British country houses, such as Chedworth or Witcombe or Bignor; but we are at least certain that the general map-pattern of Romano-British country life remained primarily prehistoric, and shows no real similarity to that of the evolved countryside of the middle ages. It may reasonably be suspected that the Roman villa system disciplined some part of Romano-British agriculture, rather than revolutionised it.

In the past insufficient weight has usually been attached to this large static element in the composition of Roman Britain. The modernity of the town- and road-map of the province is misleading to the casual glance. The Roman engineer cut his roads through miles of forest and built his causeways fearlessly across swamps, in modern fashion. The towns occupy modern valley sites at river crossings. But there the modernity of the map ends. For the rest, the fertile forest lands remained uncleared, the swamps undrained. Both alike continued to be almost as devoid of inhabitants as before the legions came. This point is a vital one. The background of Roman Britain was derived directly from Early Iron Age Britain: a background showing the downs of Sussex and of Wessex still thickly populated with peasant farmers whose agricultural equipment and general environment were almost identical with that of their pre-Roman forbears.

Roman Britain failed, then, not merely because of the increasing corruption and mutability of imperial authority, nor yet merely because of barbarian onslaught. It failed equally because it was designed by its masters as a closely co-ordinated commercial province, whereas at heart it remained essentially what it had been in the pre-Roman era—a province of nucleated but poorly equipped agricultural folk, capable of providing hardly more than sufficed their own needs, with little margin for barter. It lacked the wherewithal to balance a sustained import trade, to subsidise a permanent middle class. The new urban populations, after living awhile in a fool’s paradise, drifted steadily into pauperism, and their cities decayed into slums. The long-ruined forum of Wroxeter, the theatre of Verulamium used as a rubbish dump in a half-derelict city, are eloquent of the desperate pass to which Roman urbanity had come by the latter half of the fourth century. The Roman valley cities had failed in the purpose

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1 The heavier soils in the neighbourhood of these country houses have been so extensively tilled in the middle ages and later that actual traces of Roman tillage are unlikely now to be detected there. On the other hand, the intensive exploration of a limited area—say, 10 miles square—in a region rich in Roman country houses might be expected to provide useful hints on this point.
for which they and their highways had been primarily designed and they had no line of retreat; for their designers had divorced them, alike in place and in kind, from the simple rusticity of the pre-Roman hill towns which had in their day constituted a genuine expression of the economic condition of the country. Recovery was impossible, and the subsequent revival of the Roman cities in the changed environment of the middle ages was a tribute to the skill of the Roman engineer, rather than to the achievement of the Roman economist.

If the Romano-British towns failed, it has long been recognised that, within the strict limits already defined, Romano-British country life succeeded. When the towns, or many of them, were already in extremis, country houses (as at Bourton-on-the-Water, Gloucestershire), farms and villages (as at Woodyates, Dorset), were flourishing and rebuilding. Country shrines (Lydney in Gloucestershire, and in the Dorset Maiden Castle) were being built anew, sometimes on a lavish scale. The official religion, Christianity, in spite of the Christian complexion of the literary tradition, appears to have gained only a modest foothold in Roman Britain: its natural vehicle would have been the urban populations, but these, as we have seen, were largely 'down and out.' A single tiny chapel served the needs of Christian Silchester; another, even smaller, would appear to have served Caerwent. A short list would include the tangible relics of Christianity from the whole of Roman Britain. There were bishops in certain of the larger cities, but their flocks must, for the most part, have been the city rabble. In the remoter countryside of the fourth century, paganism, un reach ed by urban officialdom, achieved a last efflorescence before, in the tumult of the Dark Ages, Christianised denizens of the slums were cast forth into the wilds, where their urban faith and their fevered memories of urban splendour combined to Christianise the outlands and to fill them with romance.

ALEXANDER PEDLER LECTURE.

The seventh Alexander Pedler Lecture was given in Leicester, in cooperation with the authorities of the University College in that city, by Prof. Allan Ferguson, D.Sc., on Monday, May 3, 1937. The lecture dealt with some problems of surface tension illustrated by motion pictures of splashes and the text has been printed in another form in the Proceedings of the Royal Institution (Proc. Roy. Inst., 28, p. 195, Feb., 1934).
REFERENCES TO PUBLICATIONS OF COMMUNICATIONS TO THE SECTIONS

AND OTHER REFERENCES SUPPLIED BY AUTHORS.

The titles of discussions, or the names of readers of papers in the Sections (pp. 333-445), as to which publication notes have been supplied, are given below in alphabetical order under each Section.

References indicated by 'cf.' are to appropriate works quoted by the authors of papers, not to the papers themselves.

General reference may be made to the issues of Nature (weekly) during and subsequent to the meeting.

SECTION A.


Stevenson, Dr. H. A. To appear in Pharmaceutical Journ.


DEPARTMENT A*.

Full reports of the discussions on The Unification of Algebra in Schools and The bearing of higher Geometry in the School Course are printed in a special number of the Mathematical Gazette, 21, No. 246 (Nov. 1937).

SECTION B.

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Linderstrom-Lang, Dr. K. To appear in *Collegium, Zeitschr. Internat. Vereins Lederindustriechemiker*.


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Reynolds, Prof. S. H. Expected to appear in *Geol. Mag*.

Richey, Dr. J. E. Expected to appear in *Bulletin Volcanologique*.

Richter, Dr. R. Cf. 1929 *Natur und Museum*, **59**, 1–33.


SECTION D.


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Roxby, Prof. P. M. Expected to appear in Geography.


SECTION F.


Selfridge, H. G., Jr. 1937 (Sept. 9) Women's Wear.

SECTION G.

Baily, Prof. F. G. 1937 (Sept. 10) Engineering, p. 299; (Sept. 17) Electrician.


Faber, Dr. Oscar. 1937 (Nov. 12) Engineering, p. 556.

Fleming, A. P. M., and Jackson, Dr. W. 1937 (Oct. 22) Engineering, p. 499.


Sims, Dr. L. G. A. 1937 (Oct. 1) Engineering, p. 387.


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Section H.


Hooke, Prof. S. H. Expected to appear in Folk Lore.


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Lockhart, Dr. L. P. 1937 Lancet, 2, 1177.

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Cattell, Dr. R. B. 1937 (Dec.) Character and Personality.


Rodger, A. 1937 (Nov.) The Human Factor.

Spearman, Prof. C. Expected to appear in Scientia; cf. 'Psychology down the Ages' (1937).


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Section K.


Davies, Miss G. N. Cf. Ministry of Agric. and Fisheries, Rept. No. 545 Serial No. 771.

Harris, Prof. T. Expected to appear as Catalogue of Rhaetic Flora, Brit. Mus. (Nat. Hist.).


Turrill, Dr. W. B. Expected to appear in Biol. Rev. (Cambridge Phil. Soc.).


Department K*.

Fitzherbert, J. T. 1937 Colliery Guardian, 155, No. 4002, 476; Timber Trades Journ., 142, No. 3185, 800.


Pollard-Urquhart, B. Cf. 1936 (Sept.) Wood.

Wilson, Dr. S. E. 1937 Quart. Journ. Forestry, 31, No. 4, 239–51; Colliery Guardian, 155, No. 4003, 516–7; Timber Trades Journ., 142, No. 3185, 802.

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Ginsberg, Prof. M. 1937 (Oct.) *Social Review*.


Horrabin, J. F. To be published as a pamphlet by National Council of Labour Colleges.


**SECTION M.**


APPENDIX

A SCIENTIFIC SURVEY OF NOTTINGHAM AND DISTRICT

PREPARED FOR THE NOTTINGHAM MEETING 1937

BY VARIOUS AUTHORS

EDITED BY Prof. H. H. SWINNERTON, D.Sc.
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A SCIENTIFIC SURVEY OF NOTTINGHAM AND DISTRICT

I.

THE CITY OF NOTTINGHAM

i. THE GROWTH OF MODERN NOTTINGHAM

by

J. D. CHAMBERS, B.A., Ph.D.

The recorded history of Nottingham begins with the Anglian settlement on St Mary's Hill. The record consists of the name itself—Snotingaham, the homestead of the Snotings; but there are evidences in the rock on which it stands of the presence of man from neolithic times. Its soft sandstone, which lent itself to easy excavation, was an attraction to man from early to modern times—though not to the Romans—and its command of a crossing of the Trent was destined to make it a high stake in the game of national politics. The references in the Anglo-Saxon Chronicle to the disputed possession of the settlement by Anglian and Dane testify to the strategic significance of the site. Edward the Elder having fortified the old settlement, built a second burh here, on the opposite side of the river, and the Conqueror took an early opportunity of securing the town and erecting a castle. The site which he chose was the present Castle Rock, to the west of the older Anglo-Danish burh and overlooking it. It marked his intention to keep what he had won.

The geographical conditions which gave to Nottingham in time of war a special strategical importance, made of it in time of peace a busy centre of exchange for a wide area. From all directions, by land and water, trade flowed to its gates; from Hull and the eastern towns via the Trent, from Derbyshire and the west by the Derwent and Trent; valuable mineral deposits also assisted the growth of the town and as early as 1155 it became a centre for dyeing cloth and by 1348 there was a local coal trade. Nottingham alabaster was known from Italy to Iceland and as many as fifty-eight alabaster heads of John the Baptist were sent to London in one consignment.

Thus, side by side with the alarums and excursions of war there de-
veloped a more prosaic undertone of industry and trade. In 1155 Henry II granted the city a charter, and by 1448 it was a fully fledged municipality with a mayor, a shire court of its own and seven aldermen for life, who were also magistrates. From the military shell a mercantile community had emerged—the County of the Town of Nottingham.

Then followed in the 16th Century, the religious revolution of the Tudors and the rise to local predominance of a wealthy commercial class. An impressive symbol of their rise may be seen in the elaborate mansion of Wollaton Hall, built by the Willughbys in 1588 of Ancaster stone in exchange, it is said, for coal from their extensive mines.

The foundations of society were shifting and it is not surprising that in the seventeenth century the superstructure of Church and State had to be remodelled in accordance with the new ground plan evolved in the sixteenth. For religious reasons, the conflict came to open war, and Nottingham was the chosen spot for opening the local campaign. But Charles's standard waved in vain from Standard Hill; he fell back on Shrewsbury and the Parliamentarians took their chance and seized the ancient fortress—in disrepair but vitally important still.

The prompt action of Sir John Hutchinson, who took the lead in securing the town and castle for Parliament, and the stubborn defence of the castle by himself and his remarkable wife, Lucy, against the strenuous attacks of the Newarkers, were important factors in the success of the cause. By this means the crossing of the Trent was kept for Parliament throughout the war and communications between north and south secured. It was fitting—but not entirely an accident—that after the disaster of Naseby, the defeated King should haul down his flag in the county from which he issued his challenge. In the hopes of breaking the ring of his enemies, he opened negotiations with the Scottish Commissioners whose army was taking part in the siege of that indomitable town, Newark. Early on 5th May 1646, the King in disguise arrived at the Saracen's Head, Southwell, whence he was transferred, later in the day, to the Scottish headquarters at Kelham. The King was a prisoner and the war was virtually over.

From now to the end of the 18th Century the history of the town was relatively uneventful; but under the placid surface there was significant movement which expressed itself in two main directions, in architecture and in economic life. Both town and county were getting richer, and under the influence of wealth and leisure, art and enterprise were free to flourish.

The architectural heritage of the town had already been enriched by the rebuilding in perpendicular style of St. Mary's in the century 1380-1480. This is not the place to comment on this last achievement of the medieval spirit, but it offers an interesting example of the wealth of the local wool merchants, since it was largely through their munificence that the nave was rebuilt.

From this time there is no more conspicuous church building, unless we except the new St. Nicholas, until modern times; houses not churches remain to attest the spirit of the age, a spirit grounded in classical studies and rounded off by the continental tour. In 1674 William
Cavendish, Duke of Newcastle, started his palatial residence on the site of the old Castle; Nottingham now possessed a ducal seat and became a centre of attraction to the people of quality in the district. They not merely visited the town; they lived in it; and the houses which they built express the ideas of comfort and elegance belonging to their class and period. Consider such examples of aristocratic house-building as Newdigate House (1675) in Castle Gate, Willoughby House (1730-40), and Vault Hall (1743) on Low Pavement and the house of Lord Howe at the corner of Stanford Street, and perhaps especially Bromley House, built by George Smith the banker in 1732. We have only to step into the vestibule of Bromley House, look through the vista of the hall and garden, mount the ample sweep of its staircase through the leisurely gradations of its shallow stairs, to realise at once that we are in the mental climate of another age, an age of assured serenity, of patrician culture firmly based. Nottingham was basking in the full Augustan sun.

The reputation of Nottingham at this time stood high. 'Were a Naturalist in Quest of an exquisite Spot to build a Town or City upon, could he meet with one that would better Answer his Wishes?' So wrote Dr. Charles Deering of his adopted town of Nottingham in 1739, after settling there at the conclusion of a pilgrimage that had been long and arduous. He was a naturalist of some repute and had settled in Nottingham after a varied and not too fortunate career as a doctor in Germany, London and elsewhere. He was a solitary and he died destitute. But he loved Nottingham so well that he spent his slender resources in collecting material for its history and his last years in writing it up. When we look at the plan which he included in his History of Nottingham, published in 1751, we can see the reason; we may even envy him the opportunity of making such a choice. (See Plan of Nottingham in 1744 inset opposite page 8.)

The town consisted of less than 2,000 houses, containing about ten thousand people; most houses had stretches of gardens and many had orchards. This 'garden city' community of ten thousand souls was arrayed along the southern face of a sandstone outcrop, stretching from Hollowstone along High Pavement, Back Lane (Parliament Street), Butt Dyke (Park Row) to the Castle Rock; to the north and south of this sandstone crescent lay the open fields and meadows, the famous crocus meadows which in early spring spread a purple hem to the skirts of the old town. No town in England, it is said, had so fine an approach as 'the most beautiful mile' which lay through these crocus meadows between Trent Bridge and Hollowstone; and from Celia Fiennes who, in 1689 said it was the neatest built town she had ever seen, to a German traveller in 1784, who described it as one of the best, and certainly the cleanest outside London, there is a chorus of praise.

At the very time that these words were written changes were taking place that were destined to give Nottingham a reputation of a very different kind. They sprang from that potent seed, sown almost casually by William Lee, an obscure Calverton clergyman, in Elizabeth's reign. The stocking-frame, which he invented in 1589, and on which he had made a pair of silk stockings for Elizabeth herself, had grown into an industry
which employed many thousands of workers in the villages and towns of the Midland counties, and the number was continually growing. The industry clamoured for cheap labour; women’s labour, children’s labour, anybody’s labour, skilled and unskilled. By the middle of the eighteenth century the gild regulations were outgrown and labour was free.

Industrial technique kept pace with these changes. In 1759 the Derby Rib machine was invented by Jedediah Strutt, the first important modification of the original frame and the greatest. From this source flowed a bewildering succession of mechanical innovations by which the stockinger progressively mastered the art of producing almost every known mesh by mechanical means. The result was the rise of Nottingham lace, the work of an army of obscure mechanics—Flint, Rogers, Hammond, Hayne—who paved the way for the triumph of Heathcoat and Levers in the early nineteenth century.

But perhaps the greatest influence exerted by the stocking industry was in the encouragement it gave to mechanical spinning. Hargreaves and Arkwright were only the most prominent of the inventors who were floated by the finance of local tradesmen, bankers and hosiers on Nottingham’s chief industry; Hargreaves came probably in 1768; Richard Arkwright followed the same year. The mechanical power was, at first, a horse gin, but by 1771 Arkwright had set up his mill at Cromford on the Derwent and similar factories, driven by water power, sprang up along the Leen and the Dover Beck. The death knell of the water-mill sounded almost as soon as it was born. In 1785 the first power mill in the world was established at Papplewick, another at Nottingham in 1790, and the transference of the industry to the sources of labour supply in the town began.

Nottingham was thus edged nearer and nearer to the rapids of the Industrial Revolution. But two circumstances operated to check the speed of descent; the first was the swift decline of cotton spinning in competition with Lancashire, the second was the persistence of the domestic structure of the Hosiery Industry. Although a circular frame was invented by Brunel in 1816, it was not applied, in an improved form, until the ’40’s and even then for another twenty years the hand-frame maintained an unequal fight with the factory. To this day it is possible to see frames at work in a few cottages in Calverton (where the frame originated) and other centres; and the stockingers’ windows in town and village of the Midlands attest the wide distribution of the industry, and the obstinacy with which it died.

But the most spectacular aspect of the changes was the growth of population.

From 10,000 in Deering’s time it grew to 28,861 at the first census in 1801, by 1821 it was 40,415 and in 1831 it was 50,680. By the standards of the time this is not a phenomenal increase; other towns can show an even more rapid rate, but it was accompanied by a circumstance that was very rare, perhaps unique. While growing so rapidly in numbers, the town remained almost stationary in area; fifty thousand people now occupied a site very little larger than that which a century earlier had housed ten.
The reason for this was that on three sides it was hemmed in by inviolable property rights, which the owners, fortunately for later generations, refused to sell; on the north and south by the common fields over which the burgesses had rights of common; on the west by Nottingham Park belonging to the Duke of Newcastle and by Wollaton Park belonging to Lord Middleton. The result was a problem of overcrowding in the old town as grim as any to be found in England. A network of new streets and alleys was rapidly thrown up, 'a resurrection of buildings, generally without order, seated like clusters of mushrooms in a field cast up by chance' as a contemporary complained. Gradually, the gardens and orchards of Deering's map disappeared and left behind them an ironical memory of their former fragrance in the names of the streets that took their place: Plum Street, Pear Street, Currant Street, Garden Street, the Meadow Platt's. They branched off, as the map shows, in all directions, like the shots and furlongs of an open field wherever there was land enough for a new street. (See Plan of Nottingham in 1831 inset opposite page 8.)

But streets are extravagant creations; they consume land space both in front and behind, and this luxury Nottingham could not afford. Alleys were more economical, but better still were blocks of houses arranged in courts to face one another across an open drain and having no back entrance of any kind. These were the notorious back-to-back houses of Nottingham, of which there were nearly 8,000 in 1845. They were frequently built in the form of narrow courts, entered by a tunnel twenty to thirty feet long, eight feet high, and from thirty to thirty-six inches wide. Thus was Deering's Nottingham, that 'exquisite spot to build a town upon', changed into a chequer-board of mean streets, alleyways and courts, and a byword for filth and misery beyond belief.

When the Commissioner appointed in 1845 to enquire into the condition of large towns and populous places came to Nottingham he was compelled to report that the average age at death of the inhabitants of several of the Nottingham districts was only 14 or 15 years, a lower rate than had yet been ascertained to exist in any other city or town within the British Empire.

To set off against this unenviable pre-eminence, there is one achievement in the sphere of social reconstruction of which Nottingham should be pre-eminently proud. This is the wonderful revolution effected in its water supply by that remarkable man, Thomas Hawkesley, the foremost civil engineer of his age, and probably the greatest benefactor that Nottingham has ever had. He was a native of Nottingham, born of a well-known local family, and his work in the sphere of civil engineering in England and on the continent ranks among the notable achievements of the age.

Mr. Hawkesley was engineer to the Trent Waterworks, a company that was incorporated in 1825. Before the reform which he inaugurated, water was supplied to the houses of the labouring classes by means of carriers, who sold it at the rate of a farthing a bucket, or where it had to be carried any distance, a halfpenny a bucket, but after the changes carried out by Mr. Hawkesley, 8,000 houses containing 35,000 people, as
well as a number of breweries, dye-houses and steam engines were supplied by pipe lines at high pressure day and night at a cost of a penny per house per week. The cost, measured in quantity of water supplied, had been reduced, it was said, to one-twenty-sixth of what it had been formerly, and the entire supply was managed by one man and a boy. Asked by the incredulous commissioners what would happen to taps and lead-piping left all night in the house of a working man, he replied that the high pressure of the water was a sufficient deterrent to thievish intent and acted as an automatic policeman. He pointed out also, that gratitude for their priceless treasure of a permanent and plentiful supply of fresh water might also be reckoned upon, especially by the housewives to whom it was an unspeakable boon.

Within their allotted sphere Hawkesley and his colleagues worked wonders, but they were defeated in their wider aims by the political society in which they lived. Local politics, as an examination of any municipal election at this time would show, were a reflection of the struggle between rival property interests, and the focus of the struggle was the question of enclosure. The forces were very evenly balanced. While the green band of property rights hemmed in the town on three sides its further expansion was impossible. Industrialists on the look out for sites went outside the town altogether, to Basford, Bulwell, even to Arnold. Tradesmen saw themselves doomed to stagnate; business men could not expand; the building industry chafed impotently against the barrier of the common rights which prevented it from loading the surrounding meadows and fields with more slums; but above all, the owners of the common land—for it was owned in severalty though it was pastured in common—were prevented from entering into their inheritance of enhanced site values by the postponement of enclosure. Truly a formidable combination.

But enclosure was held at bay, except for a few minor concessions, until 1845. The owners of small houses in the town opposed it; their houses would be empty and they would be ruined, they said. The burgesses clung to their rights of common, though not more than 185 out of 3,000 actually used them for pasturing their cattle. But all took pleasure in the open spaces round the town, in the cricket matches on the Forest, the walks on the Lammas Lands and Meadows, the snow-balling and skating on the frozen floods. Nottingham could stretch its legs and fill its lungs; already the Basford enclosures had robbed the people, it was said, of 1,500 acres of common playground where they had formerly gone in nutting parties, and danced to the fiddler’s playing. The enclosure of Nottingham itself would stifle them. However, the political complexion of the borough changed under the influence of the new voters of 1835 and within ten years, enclosure triumphed. Public spirit had already been whipped into reluctant activity by a fearful attack of cholera; there was a team of enthusiasts at work, sharp-shooters, skirmishing on the flank of vested interests wherever they were found. Hawkesley was the most distinguished, but there were others: a doctor, a parson, a local historian, a few businessmen and manufacturers. The complex struggle of conflicting property groups, a struggle in which disinterested public spirit and expert
NOTTINGHAM IN 1744

reproduction of copy of 'Badder and Peel's New Plan of the Town of Nottingham' in the Nottingham Reference Library, by kind permission of the Public Libraries and Museum Committee.
Nottingham in 1831

reproduction of copy of 'Stavelly and Wood's Plan of Nottingham' in the Nottingham Reference Library, by kind permission of the Public Libraries and Museum Committee.
knowledge participated, had momentous consequences, and is a very interesting example of how corporate decisions are made.

In 1845 the Act was passed, and it was something new in the way of enclosure acts. It was so hedged about with restrictions and safeguards that on the land thus brought in, slums were impossible. Houses had to be of a certain size; they had to have a back door as well as a front; even a garden was insisted upon. More than this, land was to be set apart for recreation; the Forest, the Arboretum, Queen’s Walk, Corporation Oaks. It must be admitted that the provisions of the Act were not proof against the ingenuity of speculative builders, but they witness to the birth of a social conscience rare for those days, an outcome no doubt, of the foregoing struggle in which scientific knowledge, armed with an active public spirit, had played a conspicuous part. Nottingham now entered upon the course of municipal development, which has culminated, after many years of painfully slow progress, in a notable burst of energy in our own time, and placed the city in the front rank of progressive English municipalities.

ii. THE MUNICIPAL LIFE OF NOTTINGHAM

BY
J. E. RICHARDS, TOWN CLERK.

NOTTINGHAM does not depend for present fame upon past history, but one cannot overlook the City’s story, for it was in ages past that the foundations of much that is important to-day were laid. It has a past of which any town should be proud. So far as dated history goes it cannot point to anything earlier than 868 A.D. but before that, long even before the Romans came to Britain, there was probably a settlement on the spot where Nottingham has subsequently grown up.

It is not necessary in this article to deal fully with the history of Nottingham, in itself a fascinating study, but it is interesting to recall the following events which have had a direct bearing on the municipal life of the city:

Nottingham’s first Charter was granted by Henry II in 1155,

Henry VI granted a Charter in 1448 constituting the town a County of itself,

The town was created a City by a Charter granted by the late Queen Victoria in the year 1897, and

King George V in the year 1928 raised the office of Mayor to the dignity of Lord Mayor.

From the middle of the 18th century a change took place in England and especially in the Midlands and the North. This change has been called the Industrial Revolution and its result was to turn what had been an agricultural community into an industrial one. Nottingham became a great industrial town and the coming of canals and railways gave it the
position to which its geographical situation entitles it. The industrial
development of the town was closely allied to the growth of the lace trade,
but it is no longer dependent on a ‘staple trade’ only, for it is now known
as the City of innumerable industries.

In addition to the manufacture of lace the following industries are
carried on: hosiery, bleaching, dyeing and dressing, engineering, bicycles,
clothing, leather, pharmaceutical products, brewing, malting, tobacco,
printing, and many others.

Nottingham is fortunate in its municipal and social services, in the
administration of which the manufacturing interests of the city are given
sympathetic consideration. Gas, electricity, water and transport ser-
vice are municipally controlled and managed on sound and successful
commercial lines. It also has a fine educational system culminating in a
University College.

The following is a short résumé of the public utility and health ser-
vice of the city which have helped to establish Nottingham’s claim to be
one of the most progressive municipalities in the Country.

WATER

Water is obtained from wells, sunk in the Bunter Beds of the new red
sandstone, and from storage reservoirs situated about fifty miles from the
city, in the heart of the Derbyshire Peak District. The Derwent water
from Derbyshire is of a soft quality and, like the sandstone water, shews
by analysis a high standard of purity. The Derwent supply is delivered
into the north-west portion of the Nottingham area, at the boundary of
the Langley Mill and Eastwood parishes, the pressure being sufficient to
gravitate water into the Ramsdale Hill Reservoir. The elevation of this
reservoir is about 500 feet above Ordnance datum, and thus exceeds all
the high points within the city and surrounding district. About 32 per
cent of the city’s total water consumption is derived from the Derwent
supply, and the other 68 per cent from the Corporation’s own sandstone
wells.

The total area within the compulsory limits of supply as defined by the
various Acts of Parliament and Provisional Orders, is about 243 square
miles. In addition, there are parishes supplied, by agreement, outside the
Parliamentary area. The bulk of the water is supplied from five pumping
stations situated at Basford, Bestwood, Papplewick, Burton Joyce and
Boughton, being pumped direct from wells and boreholes into eight
covered service reservoirs from which it gravitates to the premises supplied.

The total quantity of water distributed during the year ended March
1937 was 5,048,709,538 gallons, equal to nearly 22½ million tons, an average
of over 13½ million gallons per day. Of this quantity about 17 gallons
per head per day were used for domestic purposes, and about 12½ gallons
per head per day for trade and special purposes. The estimated popu-
lation supplied at the end of March 1937 was 460,000. Water is retailed
to consumers and small traders at a fixed annual charge, varying according
to the gross rateable value of the premises occupied, and to large traders
at so much per thousand gallons passed through meters. The maximum
pressure in the mains is about eighty pounds per square inch. The total
length of cast iron supply mains within the area is about 790 miles.

Water is supplied by the Corporation practically at cost price.

**Electricity**

Nottingham is particularly fortunate in its electricity supply. The Electricity Department of the Corporation is wholly responsible for the generation, distribution and administration of electrical energy in Nottingham and a large surrounding area. It is probably one of the most modern and progressive supply undertakings in the country, and its consumers approximate to 100,000.

A modern super-generating station, with a capacity of 30,000 Kw. was erected in 1925, an extension comprising 27,500 Kw. in 1928 and a further 30,000 Kw. came into operation at the end of 1935. This station ensures a cheap and abundant supply of electricity for all purposes.

Whilst this super-generating station (one of the selected stations under the Government Scheme) is located on the north bank of the Trent well away from the centre of the city, the entire administration is efficiently carried out from centrally situated offices in Talbot Street.

The number of units sold during the twelve months ended the 31st March 1937 was 128,637,475; and 109,156,510 units were exported to the grid scheme of the Central Electricity Board.

Up-to-date electricity showrooms have been established in the new Exchange Buildings—the very heart of the city—where every possible assistance is accorded to consumers and prospective consumers.

**Gas**

The Gas Area extends far beyond the city boundaries and includes 650 miles of mains, spread over the total area of 140 square miles. The number of consumers is 124,000 and the total quantity of gas sold per annum is 2,700,000,000 cubic feet. There are three manufacturing stations—Basford, Radford and Eastcroft—each of which is equipped with modern plant of ample capacity for the district. In addition, some 700 million cubic feet of gas is purchased in bulk from the Pinxton Coke Ovens eleven miles distant.

The Department carbonizes approximately 150,000 tons of coal annually, and the works are complete with coke screening, cleaning and grading plants which prepare 75,000 tons of smokeless fuel for use in domestic and industrial furnaces and stoves.

The special care given to ‘Nottingham Coke’ over many years has resulted in a very large increase in its demand for domestic and industrial use, and this is a contribution to the abatement of smoke in the city.

Over 2,300,000 gallons of tar are produced annually, and the whole is distilled at the Department’s tar distillation plant, producing large quantities of British road tar, creosote, naphtha, light oils, carbolics and pitch.

The Ammonia Works produce 1,750 tons of artificial manure (neutral sulphate of ammonia) per annum, and the Sulphuric Acid Works at
Giltbrook manufacture the whole of the 1,600 tons of sulphuric acid required by the Department. There are large distribution workshops and stores situated in Woodborough Road where all work for the service of consumers is carried out. The workshops control the maintenance of 124,000 meters, 90,000 cookers, 33,000 fires, as well as all special gas appliances (including water heaters, wash boilers, central and domestic heating water boilers) in the area.

The showrooms, which are well equipped and stocked, are situated in Parliament Street in the centre of the city.

**Passenger Transport**

The first passenger transport services which ran in the city were operated by horse tramways and began in 1878. These were subsequently taken over by the Nottingham Corporation and replaced by electric trams, the first route being opened in 1901.

Electric trams were the chief means of passenger transport until 1920 when the Corporation inaugurated a petrol omnibus service. The trams have gradually been replaced by trolley vehicles and petrol and oil omnibuses and were discontinued on the 5th September 1936.

At present the omnibus fleet comprises 190 modern vehicles consisting of petrol and heavy oil engines, serving routes in the city and districts outside.

In addition, the Corporation operate trolley vehicle services. The first service of this kind was inaugurated in 1927 and there are 23.2 route miles now operated by this class of vehicle. The services are maintained by a fleet of 125 of the latest type six-wheeled vehicles.

The total distance of routes covered by the various services of the Corporation now amounts to 136 miles. The development of the undertaking is best demonstrated by a comparison of the passengers carried and the miles run in the first year of operation by the Corporation, which was in 1898, and the last available year, viz., year ended 31st March 1937. Thus we find that the number of passengers has increased from two and a half millions to over one hundred millions, and the miles run have increased from a little over a quarter of a million to over ten millions.

The Department is well equipped with regard to workshops for maintenance, and all classes of repairs are undertaken at the Trent Bridge Works. The main depot and offices are situated at Parliament Street where accommodation is provided for 225 vehicles of all types with shops for running repairs. There are two other depots situate in outlying districts.

**Airport**

The city has always been to the forefront in the matter of aviation. In 1928 the City Council established an airport at Tollerton, 3½ miles from the city centre. The airport has the distinction of being the second to be licensed in this country.

The aerodrome originally covered an area of 140 acres, but with a view to an increase in the size of the landing area and the protection of
the airport against development along its perimeter which may interfere with its approaches and runways the Corporation have entered into negotiations for the purchase of land which will increase the area to approximately 630 acres. Its unique position will, as aviation progresses, make it one of the most important airports in the country.

Special taxi and charter work is undertaken at short notice at moderate rates. Nottingham Airport offers first-class accommodation, servicing, repairs and maintenance at very low rates. A qualified staff of experienced pilots and engineers is kept fully employed.

TRENT NAVIGATION

The River Trent affords Nottingham a highway to the sea. It gives access to Newark, Gainsborough, and four Humber Ports, including Hull.

Prior to the Great War the navigation was controlled by a Company, but by the Nottingham Corporation (Trent Navigation Transfer) Act. 1915. the portion of the navigation lying between Nottingham and Newark was transferred to the Corporation.

On the conclusion of hostilities the Corporation exercised their powers under the Act and have since pursued an energetic policy of constructing new locks (Stoke Bardolph, Gunthorpe, Hazleford and Holme Pierrepont) and deepening the river. At the Nottingham end of the section controlled by the Corporation, basins, warehouses and transit sheds have been constructed. An enormous tonnage is cleared every year.

In addition to the river service with the Humber Ports there is a canal service via Leicester and the Grand Union Canal between Nottingham and London and also services between Nottingham and Birmingham, Manchester, Liverpool, &c.

NEW ROADS

Prior to the War, Nottingham had some fine roads, notably, Gregory Boulevard, Lenton Boulevard and Radford Boulevard, but with the ever increasing motor traffic new problems of town planning arose. With a view to solving these problems several magnificent new arterial roads have been constructed. Taking advantage of grants from the Government the Corporation first constructed Valley Road (80 ft. wide and 1.75 miles long) through an area hitherto undeveloped.

Other new arterial roads have been constructed as follows: —Middleton Boulevard, 120 ft. wide and .72 miles long. Western Boulevard, 120 ft. wide and 1.93 miles long. These roads have dual carriageways and have served the purpose of opening up undeveloped areas, relieving traffic congestion and enabling traffic passing through the city to do so without having to negotiate the busy areas in the centre.

The construction of the extension of Parliament Street, through the heart of the city, connecting districts South of the city with those of the North, was carried out partly in connection with the demolition of slum property. This new road, which is practically half a mile long and has a minimum width of 70 feet, has done much to relieve traffic congestion.
The Town Planning Scheme contains other proposals for the construction of new roads and widening of existing roads, and when these works have been completed, traffic difficulties in Nottingham will be reduced to a minimum.

**HOUSING AND RE-HOUSING**

The progressive policy adopted by the Corporation Housing Committee has resulted in Nottingham being right in the forefront of municipal housing.

Immediately after the War, Nottingham, in common with all other Cities, was faced with a serious Housing shortage. The Housing Committee embarked upon an extensive housing policy covering a considerable number of estates, and since 1919 no less than 15,000 houses for the working classes have been built.

Nottingham has been fully alive to its obligations in respect to slum clearance and its five years' programme for this work provides for the erection of approximately 5,500 new houses.

It is of interest to note that Nottingham was the first large city in England to send in a completed five-year plan for slum clearance and also the first large city to receive approval for that scheme from the Ministry of Health. 2,500 houses have been completed for re-housing in connection with slum clearance and work is proceeding on a further 3,000 houses to complete the programme.

Nottingham was one of the first local authorities to erect houses to let at an economic rent without the aid of Government subsidy. 550 non-parlour houses have been erected and let at an inclusive rent of 10/2 per week, and another 1,000 are in course of construction.

In accordance with the provisions of the Housing Act, 1936, 66,835 houses have been inspected, of which 1,015 or 1.517% were found to be overcrowded. The scheme for dealing with overcrowding provides, in the first place, for the erection of 308 houses and it is the Corporation's intention to deal with this matter expeditiously.

The Ministry of Health has warmly commended the Corporation upon its housing developments and has frequently used its figures as a basis of comparison. The general excellence of its housing schemes, combining successful layout, sound construction, artistic appearance and lowness of cost has led to the results being studied by the corporations of many important centres.

**PUBLIC HEALTH SERVICES**

In a municipality of highly developed and methodically administered public services, matters appertaining to public health claim the highest consideration. In view of the important part which the health of an industrial community plays in its prosperity, the Public Health Department of the Corporation has a very responsible trust to administer. Every modern resource is utilized to combat disease, both by prevention and cure. To this end the latest methods of applied sanitary science are turned to account. Full use is made of the powers conferred by the Infectious Diseases (Notification) Act, and disinfection and isolation are carried out whenever necessary. Every effort is exerted towards the
suppression of food adulteration, meat inspections are carried out, and, where required, there are facilities for the free supply of pure milk for infants. All the various aspects of maternity and child welfare work are included in the good work of the Public Health Department, whose activity bears fruit in an increasing standard of public health, and a considerable decrease in the annual death rate.

Hospitals and Clinics

The following hospitals are controlled by the Corporation:—

The City Hospital—a large well-appointed general hospital of 985 beds, undertaking every type of medical and surgical work for all classes of the community.

The City Isolation Hospital—125 beds for infectious disease, and 75 sanatorium beds for tuberculosis. There is also an auxiliary hospital for small-pox.

Bulwell Hall Sanatorium for Children—50 beds for tuberculous children in an open-air hospital school recognized by the Board of Education.

There are Six Clinics for Expectant Mothers and eleven Infant Welfare Centres situated in various parts of the city. There are also clinics, dealing with tuberculosis, venereal diseases and ultra-violet ray treatment. There is also a well equipped bacteriological laboratory.

The City Mental Hospital was established by the Corporation in 1880 and has been extended from time to time, the latest addition being made in 1935 in the form of a female admission hospital and convalescent villas. The Hospital contains accommodation for the treatment of over 1,000 patients.

The Aston Hall Mental Deficiency Institution is situated in Derbyshire, some 14 miles from the city. This Institution is up-to-date in every way and is capable of dealing with 320 patients.

Public Baths

Nottingham is well served in the matter of public baths, which count for so much in preserving the health of the citizens. There are eleven bathing establishments in the city and at several of them various types of accommodation are grouped within a single unit. The following facilities are provided:—

7 covered swimming baths
3 open-air pools
1 river bath
230 slipper baths
5 public wash-houses
Turkish Baths with all modern equipment

Main Drainage and Sewage Disposal.

On the 8th September 1936, Nottingham's new Main Drainage Scheme and Sewage Disposal Works were inaugurated. This was the culmination of a scheme of works under powers obtained in the Nottingham Corporation Act 1929.
The new sewerage system is of sufficient capacity to deal efficiently with the present and future requirements of the city and adjoining urban and rural districts.

The object of the new Sewage Disposal Works is to increase the filtering capacity of the land by means of preliminary treatment. The estimated cost of the Sewerage Works is £748,440, and that of the Disposal Works is £332,960, making a total for the whole of £1,081,400.

**Parks and Open Spaces**

Nottingham is generously endowed with public parks and open spaces which, apart from the opportunities they afford for recreation and amusement, play an important part in the excellent standard of public health enjoyed by the city. Approximately 1,500 acres are set aside as Parks and Recreation Grounds, and facilities are provided for every kind of sport. There are three golf courses within the city boundary.

In 1931 Sir Julien Cahn presented to the city the historic Newstead Abbey, important because of its intimate associations with Byron. Newstead is about nine miles north of the city and is a rich inheritance for future generations of Nottingham citizens. At the same time as the gift of Sir Julien, Mr. Charles Ian Fraser gave to the city the Hut Entrance Lodge together with the celebrated Pilgrim Oak and an area of land in the Park comprising 74.87 acres, the six-acre wood known as the 'Poet's Corner' and other valuable gifts associated with Lord Byron. The Abbey and grounds make a delightful rendezvous for the people of Nottingham.

Wollaton Park and University Park are the most recent acquisitions. Within a few minutes from the centre of the city is Wollaton Park with its magnificent Elizabethan Hall, its noble trees, its lovely lake, its sylvan charms, is bracken and its deer. The Park and its mansion, Wollaton Hall, covering 744 acres were purchased by the Corporation from Lord Middleton in 1924. The park is open to the public and on part of it a first-class golf course has been laid out.

University Park occupies about 150 acres and includes a boating lake of some 14 acres. This park was created by the munificence of the late Lord Trent. It is magnificently laid out and gives recreational facilities for children and adults.

It is not possible to enumerate the advantages of the various parks and grounds, but Nottingham is considered to be one of the most fortunate municipalities in this respect in the country.

**Public Libraries**

In keeping with the progressive character of the city, Nottingham has liberally provided its citizens with opportunities for reading and the cultivation of a taste for literature, and students with opportunities for home study.

The Central Library comprises a well-stocked lending library, reference library, reading room and news-room.

The district branch system comprises seven lending libraries with reading rooms and another branch is being erected in the Aspley district.
MARKETS

The market rights for the city are vested in the Corporation by authority conferred by ancient Charters.

From the earliest times all sections of the market were held in the central square known as the Great Market Place. In 1869 the Cattle Market was moved to a separate site, and in 1900 the Wholesale Fruit, Vegetable and Fish Market was separated from the general Market and established in Sneinton Market. The final separation of the markets took place in 1928 when the whole of the remaining market was removed to another central site, the old site being laid out as an ornamental square, designed to harmonise with the new Council House.

The Central Market is a general retail market in a modern building well equipped with every convenience and is acknowledged to be one of the finest in the country.

The Cattle Market is 9½ acres in extent and provides accommodation for 1,000 beasts, 3,000 sheep, 400 pigs and 300 calves. Adequate covered lairage accommodation is given.

Two markets are held weekly, one on Mondays for fat stock and the other on Saturdays for store animals.

A new Wholesale Fruit and Vegetable Market with Country Produce Section is in course of erection and when completed will provide first-class facilities for this class of market.

The famous Nottingham Goose Fair was removed in October 1928 from the central site, which it had occupied for many centuries, in consequence of the Council House Scheme. An excellent site was found on a part of the Forest Recreation Ground and the Fairs which have been held there have been most successful.

Slaughterhouse. Increasing demands have necessitated the provision of additional accommodation and a new slaughterhouse, costing £28,800, is nearing completion.

CORPORATION ESTATES

Few cities are as fortunate as Nottingham in the possession of large corporation estates. Three of these estates are of ancient origin and yield very substantial revenues for the local exchequer. The Corporation have also purchased other large estates, notably Wollaton Park Estate and the Bulwell Hall Estate.

The shrewdness which characterizes their management cannot be better illustrated than by reference to the Wollaton Park Estate, which was purchased from the late Lord Middleton for £200,000. So well has the scheme been handled by the Estates Committee that, after reserving over 500 acres for recreative purposes and devoting a portion of the park to municipal housing sites, the Corporation have recovered almost the whole of the money that was paid for it, and has also the splendid old mansion, now used as a natural history museum.

The Corporation own other estates, including a number of sites admirably adapted to industrial development.
POLICE AND FIRE BRIGADE

The City Police Force is well-known throughout the police world as one of the most efficient forces in the United Kingdom. It has been organised on the most modern lines and was one of the first police forces to install the police telephone box system. It was also the pioneer of the police wireless patrol system and one of the first forces to mechanize. Among other modern developments are a criminal record office, fingerprint section and a foreign enquiry section.

The Fire Brigade equipment includes six high-powered pumps with escapes, an 87 feet turntable ladder, a fire tender, and a first-aid van with sets of self-contained breathing apparatus, smoke helmets, searchlights, oxy-acetylene cutting appliances, resuscitating apparatus, stretchers, &c. The Brigade is also equipped with up-to-date workshops and apart from fire prevention, fire extinguishing and the maintenance of its own equipment, it constructs bodies for such vehicles as ambulances, police patrol and wireless cars.

ART GALLERY AND MUSEUMS

The city's art collection is housed in Nottingham Castle, an outstanding landmark in the city. The Castle Rock rises on its south side to a height of 133 feet and the Castle, built on the summit of the Rock, is leased by the Corporation for 500 years from the Duke of Newcastle.

The building is very suitable for the purpose of a museum and art gallery and the collection and pictures are most interesting and valuable. In addition to the permanent collection, private collections are exhibited from time to time. In the year ended 31st March 1937, 266,967 persons visited the Castle.

Wollaton Hall is now the home of the NATURAL HISTORY MUSEUM. The collection as a whole is considered to be one of the best in the provinces.

EDUCATION

Nottingham's educational system is dealt with in a separate article (written by the Director of Education) in this handbook.

CIVIC DEVELOPMENTS

During the post-war years Nottingham has developed with amazing rapidity. One of the most outstanding developments has been the completion of a scheme for utilising to the best advantage the great market square and the Old Exchange Buildings. On the site of the old buildings now stands one of the handsomest civic buildings, and its dignity and beauty are enhanced by the modern layout of the square which was formerly known as the Great Market Place.

At the head of the first flight of the Grand Staircase, standing in an arched niche, is a fine statue, the gift of Sir Julien Cahn, depicting the Spirit of Welcome. Nottingham is always pleased to welcome visitors, and the civic pride of its citizens is justified by its honourable past and modern achievements.
Education can never stand still, it must either go onwards or it will slip back. This has been and is still clearly recognised in the City of Nottingham. In the past, Nottingham has done its part in initiating advances, and it is still continuing to do so. It was from Nottingham in 1873 that the first request was sent to Cambridge University to aid the higher education of the working classes, and from this request sprang the University Extension Movement. The first course of the University Extension Lectures was given in the Mechanics Institute, Nottingham, in October 1873.

The Nottingham Corporation was the first Corporation in the kingdom to take over the administration of a University College and to become responsible for its maintenance. The decision was made in 1881; in that year a penny rate (£2,575) was voted for the purpose. The actual cost of maintenance was then £6,515. In 1888 it was one of the earliest to become responsible for the conduct and maintenance of a School of Art. This is now the City College of Art.

The system of Recreative Evening Schools which later formed the basis of the Social Institutes, had its rise in Nottingham in 1883.

Nottingham’s Education owes great debts to its public-spirited citizens and to generous donors.

The earliest benefaction for secondary education was that of Dame Agnes Mellers, who endowed in 1513 the school now known as the Nottingham High School for Boys. Dame Agnes was the widow of Richard Mellers, Bell Founder, Mayor of Nottingham in 1500 and 1506. In the foundation deed of the school, she provides for an annual service at St. Mary’s on the anniversary of her husband’s death, to be followed by distribution of bread, ale and cheese to the Mayor, Aldermen and certain others who, if they had attended the service ‘from the beginning to the endinge thereof ’ were to receive certain sums, including sixpence for the Mayor. This picturesque ceremony is still carried out each year.

This original endowment was later increased by eighty Citizens of Nottingham and by Sir Thomas White, a Lord Mayor of London. Further benefactions have been received from time to time, especially in and after 1868, when the School was moved to its present commanding position on the sandstone ridge north of the city centre, between two public parks. Additions have been made to the buildings at frequent intervals, recent
acquisitions being a new block of classrooms, a new gymnasium and a beautiful hall with organ and complete dramatic equipment, a gift from an old boy and present Governor of the school.

In adult education, Nottingham has always been in the forefront. In 1798 the Quakers founded an Adult School, the parent of the many existing Adult Schools. In 1816 the Bromley House Library was founded and became the centre of intellectual life in the town. In 1837 the Mechanics Institute was founded. This Institute was burned down in 1867, and it was from a meeting held to discuss its rebuilding that there came the first idea of a University in Nottingham.

In 1846 the People's College was founded for the mental and moral improvement of the labouring population, clerks, warehousemen and others receiving wages or salaries for their services. This College has had a varied career. It was transferred to the School Board in 1879, and was made a Higher Grade School. Since that time it has been a Senior Mixed School and a Selective Central School, and it is now a District Central School for Boys in the daytime and a Senior Evening Institute in the evenings.

In 1843 a School of Design was founded for furtherance of industrial art. It was at first maintained largely by voluntary subscriptions. In 1863 the School was erected on its present site in Waverley Street, the site having been presented for the purpose by the Corporation. The cost of the building was £20,000, which was defrayed by voluntary subscriptions. The building was opened in 1864; responsibility for its maintenance was undertaken by the Corporation in 1888 as stated above.

In 1875 an anonymous donor gave £10,000 to provide an income to pay University Lecturers in the City, and the Corporation practically at once decided to erect a University College. The Foundation Stone of this College was laid by the Mayor in 1877 in the presence of Mr. W. E. Gladstone, and the building was opened in 1881 by H.R.H. Prince Leopold. In 1919 Sir Jesse Boot made his first gift of £50,000, of which £30,000 was appropriated to the Building Fund of the College. After that date Sir Jesse Boot (later Lord Trent) spent over £500,000 in purchasing and laying out University Park, and in erecting thereon the present University College. This College, standing on a height overlooking University Park, is a landmark to all entering the city and a fitting memorial to Nottingham's greatest benefactor. Its erection has made possible work which could not be attempted in the cramped quarters of the old University College. Now practically the whole of the university work has been transferred to the new buildings, leaving the old University College to house the technological courses.

Both sides of the work have benefited from the increased accommodation. On the University side, the number of full-time and part-time students engaged in work of University standard has increased to over 800, necessitating the building of additional hostels. On the Technological side, large extensions have been made in the old building to the laboratories for mining and for textiles. In adult education the legacy for extra mural studies now provides University extension and tutorial classes for over 4,000 students resident in the East Midlands area.
Secondary education is provided in the High School for boys with 500 on its rolls, the High School for girls (500), in the City's Municipal Secondary Schools, viz., High Pavement Boys' School (720), Mundella Mixed School (570) and Manning Girls' School (520), and in the County Education Committee's Schools, Brincliffe School for Girls' (160), and Henry Mellish Boys' School (490).

The High School for Girls, opened in 1875, was the fourth school founded by the Girls' Public Day School Trust, and after Norwich, the first one in the provinces. The High Pavement School, founded in 1788, was transferred to its present site in 1895. It was the first unsectarian school in England and also the first organised Science School in the country. When the Manning School was built in 1931, the High Pavement Secondary School, formerly a mixed school, became a Boys' school and its facilities for practical instruction were greatly increased. Plans for a new Modern School for Boys to be erected by the City Authority have been approved by the Board of Education, and it will be erected on the Bestwood site, north of the city. Mundella School is now the only co-educational secondary school in the city.

In secondary education an agreement has been made between the county and the city authorities under which parents residing in either of the two areas have choice of the secondary schools which have been built in the city by the two authorities. This agreement does away with some of the travelling difficulties for pupils. The County Education Committee are at present building a Secondary School for boys and girls in West Bridgford to replace their existing Mixed School.

In elementary education the changes have been most marked. The schools have been reorganized. This reorganisation has involved far more than the mere transfer of boys between the ages of 10½ and 11½ to central schools. Changes have been made in all departments of the schools in their staffing, equipment, curricula, and in the methods of teaching.

As a rule the schools have been divided into three classes—infants' schools for children up to 7 or 8 years of age, junior schools for boys and girls from 7 or 8 years of age to 10½ or 11½ years of age, and central schools for boys and girls over 10½ years of age. No nursery school has been formed, since it is considered that young children can be educated more efficiently and more economically in well-equipped nursery classes attached to infants schools than in separate nursery schools.

In the central schools, 30 in number, with 12,000 pupils on their rolls, the sexes have been separated, and with the exception of two schools the girls are taught in girls' schools under headmistresses with women assistants, and the boys in boys' schools under headmasters with men assistants. In the two schools which contain both sexes, the boys and girls are taught in different classes. It was considered that only by the separation of the sexes could education suitable to each be developed without undue regard to tradition. In particular, it was felt that girls' education in the past had been influenced too much by the courses of study adopted for boys, and by the requirements of universities and their examining bodies, and that it was only right that there should now be freedom to experiment with other systems of training and instruction.
This separation of the sexes at or about the age of 11 years has also been carried out in the schools for the physically and for the mentally defective children and in the large junior schools. No distinction has been made between the various senior schools in their staffing, equipment, size of classes, or in the conditions of admission of their pupils. Each school is fully equipped to give a good general education. The schools are non-selective, each having its own district of supply, and each admitting from that district all the pupils of the appropriate ages who do not join secondary schools.

It has been considered that it would have been both unwise and unfair to provide special training and staffing for the select few and to let the great majority, less well endowed pecuniarily or mentally, be taught in worse buildings with a narrower curriculum and inferior means of instruction.

Each of the central schools has therefore been equipped with special rooms in order that there may be given on the school premises, and with its own staff of specialist teachers, practical instruction in arts and crafts, science, physical training, gardening, handicraft and/or domestic subjects.

Each senior school is large enough for satisfactory classification of its pupils, since the numbers on the rolls vary from 320 to 560. There are in each year, therefore, three to five parallel classes. Each school has a multiple bias, and therefore pupils in their third and fourth years can study such subjects as are considered to their advantage, and it is not necessary for a decision to be made at the too early age of 11 years as to which type of curriculum they shall receive at the age of 14 or 15 years.

During the reorganisation, 25 schools with an accommodation for 5,000 children have been closed, and 22 schools with accommodation for 9,500 have been built. Actually, 8 only of the 30 central schools are in new buildings. In the remaining 22 central schools, rooms had to be erected or adapted as gymnasia or for instruction in art, science, handicraft and domestic subjects. The new schools, whether for normal children or for physically or for mentally defective children, have been built on the open-air plan with ample provision for school gardens and large playgrounds. In many of the older schools, which must still be used, large french windows or casement windows have been made, so as to provide more light and air and to make the schools really homelike, and less like disused prisons.

When planning the new schools in the new housing estates in the city, the Education Committee had in mind not only the provision of facilities for a good general education for school children of all ages but also for social gatherings of the inhabitants in the evenings and in school holidays. With this idea in view, there was allocated on each housing estate, and generally in the centre of it, a school site varying in size from 10 to 25 acres. The schools were planned so that their use for social functions in the evening would not interfere with the day school work, or with those out-of-school activities which form so important a feature in modern day-school education. It was borne in mind, also, that the schools would be required for the purposes of evening institutes for the further education of adolescents and adults. The schools have not only been planned, but
also equipped and furnished, with these purposes in view. The seating accommodation consists not of desks but of tables and chairs.

The planning of these new schools can be best illustrated by a description of the largest of them—the William Crane Schools of the Aspley Housing Estate, an estate of over 4,000 houses. The schools are worthily named after the Chairman of the Housing Committee and of the School Buildings Committee, to whom Nottingham owes a great debt of gratitude. They were formally opened by the Archbishop of York in 1933. On a central circular site of 12½ acres, six schools have been built round a playing-field of 2½ acres. The schools consist of a senior boys’ school and a senior girls’ school, a junior boys’ school, a junior girls’ school and two infants’ schools, with a total accommodation for 3,000 pupils. Between each junior school and an infants’ school there is a large hall which will seat over 1,000 persons. One of these halls has a large stage with a sloping floor, the other has a smaller stage. On each side of the hall are lavatories and offices for both sexes, approached by covered ways. One of the halls has a movable boxing ring and is marked for badminton. Below each hall is storage for the chairs.

Each senior school contains nine classrooms, a gymnasium, two school clinics, an art room, a science room, and a craft room. The girls’ school has also two domestic subjects rooms equipped with gas, coal and electric stoves. The boys’ school has a metalwork room and a woodwork room divided from one another by a soundproof partition. The large play-grounds are marked for tennis, netball and other games, and are used both in the day and in the evening. There is a large canteen which can provide meals for 200 persons at a sitting.

A school nurse attends to minor ailments of the children under the supervision of the Committee’s medical officer. Each school is provided with a school garden. There are also school orchards, two greenhouses, cold frames, beehives and lily ponds. There are only four entrances to the schools, two of which lead directly to the large halls. The central playing-field is not large enough for the general requirements and could well have been made larger. There is, however, close at hand a public recreation ground and a 10-acre school playing-field.

The school has been open since 1931, and not only provides education for 3,000 children but also accommodation for an evening institute for girls and women, an evening institute for boys and men, for meetings of Girl Guides, co-operative guilds, W.E.A. classes, University tutorial classes, for religious organizations on week-days and on Sundays, and also for a large self-governing social centre consisting of residents on the estate. The social centre has its own monthly magazine, a sports section, a debates section, a horticultural section, and a recreation section which supervises whistdrives and dances and other social functions.

At the present time three schools are in course of erection, the Mapperley School with accommodation for 450 with a Hall specially planned so that it will not only fulfil the requirements of its day pupils, but will also serve for social purposes and dramatic performances in the evenings and school holidays, the Whitemoor School extension, accommodating 450, with its stage for dramatic performances, etc., and the John Player School
on the Bilborough site, which will provide accommodation for 3,000 children from 2 to 15 years of age in six departments. This school will have all the facilities now provided in the William Crane School, and in addition two fully equipped gymnasia and complete accommodation for children between 2 and 5 years of age.

The schools therefore are the centre of the estate life, and answer their varied purposes admirably. The use of the buildings in the evening by adults and adolescents, while not interfering with the day schools, has given rise to a more active interest in the day school work than generally is obtained. It has also been the means of fostering a communal spirit among the residents and a communal pride in the estate and its schools.

This policy of using the schools for social purposes has been pursued in each of the 15 central school districts of the city. The social side of the work has also been developed in the evening institutes for men and women in the city, and this has partly been the cause of the greatly increased number of students attending those institutes, and the regularity of the attendances of the members of the institutes.

While improving facilities for education in the schools, the Committee have not lost sight of the necessity of attending to the health of their children. They have in the last twelve years opened a large central clinic with thirteen beds and have built two other fully equipped school clinics in addition to the smaller ones attached to new and old schools. They have also increased the playing-field accommodation to a great extent, though much still requires to be done in this connection.

Though the education progress has been rapid in the city during the past twelve years, the Committee are well aware that they have not reached perfection. The schools must change with the changing times.
In modern times the city of Nottingham has been chiefly renowned as the home and headquarters of the lace industry, and although a growing multitude of other industries is now to be found, it is still primarily a centre of textile manufacturing. Owing to its position near the banks of the Trent, Nottingham has long controlled one of the great river-crossings of England, whilst its present-day communications make it a route centre of vital commercial importance. At its door lies part of the richest coalfield in the country. Several collieries are actually situated within the municipal boundary and the proximity of coal has inevitably played a leading part in local industrial development. To-day the city and its suburbs contain more than 325,000 inhabitants (the city population alone at the census of 1931 being 268,801) so that, after Birmingham, Nottingham ranks with Stoke-on-Trent (276,639) and Leicester (240,000) among the largest cities of the Midlands.

There are at least three different ways, in the regional sense, of regarding Nottingham as a centre of importance. In the first place, since it has always been of greater size than its two neighbours, Leicester and Derby, it has some claim to be considered the capital of the East Midlands. It is difficult, however, to define the limits of the East Midlands for in the absence of clearly marked natural boundaries the extent of this region varies for different purposes. The East Midland Educational Union, for instance, serves the counties of Nottingham, Derby, Leicester, Rutland, Northampton, the Soke of Peterborough and the Kesteven and Lindsey divisions of Lincolnshire, whereas the territory falling under the jurisdiction of the East Midlands Traffic Commissioners includes the counties of Nottingham, Lincoln (except parts of Holland), Leicester, Rutland, Northampton, Oxford and parts of Derby, Bedford and Buckingham. Again, the East Midlands division of the Criminal Investigation Department with its new forensic laboratory at Nottingham controls operations over the immediately surrounding counties, together with Huntingdonshire and Norfolk. For all these and many other organisations Nottingham serves as the natural headquarters and enjoys a long tradition as an unchallenged centre. Consequently, there is a certain public consciousness of the identity of the surrounding region. Certainly the people
who live here feel themselves to belong to a province different and distinct from that of Birmingham, Coventry, Warwick and Lichfield. They are not merely Midlanders, but East Midlanders, and their land is essentially that watered by the Trent and its middle tributaries, a region which embraced the earlier portions of the ancient kingdom of Mercia.

Then, too, Nottingham is the county town of Nottinghamshire, a distinction carrying special emphasis in a shire in which there is no other large centre. Here the combination of administrative functions, educational and cultural activities, entertainments and shopping facilities together with the transport services are singularly concentrated in one city. County administration, in point of fact, is conducted from the Shire Hall, the buildings of which occupy a single acre in the heart of the city and constitute an independent parish of the county! Yet instead of being centrally situated, Nottingham lies much nearer the southern extremity of the roughly oval-shaped county and this fact, bearing in mind the close juxtaposition of the neighbouring shires, has caused our city to develop important contacts with such centres as Grantham, Loughborough, Derby, Ilkeston and Long Eaton. Local topography, by providing easy routes has undoubtedly encouraged these connections. No less than forty-two trains, excluding goods trains, run daily each way between Nottingham and Derby and Loughborough respectively. Two-thirds of the trains to and from Derby follow a virtually level track across the Trent and Derwent floodplain, whilst the routes to Loughborough and Leicester are facilitated by the Soar valley and the flat expanse of Ruddington Moor. Since, also, the textile industry of Long Eaton, chiefly machine-lace, grew as an offshoot from that of Nottingham, the close relations between these centres will be obvious. By numerous and frequent bus services as well as by rail, Nottingham is connected with the populous districts of the Erewash valley and with such centres as Heanor which lie beyond.

Thirdly, the city of Nottingham is the life centre of a still smaller region or district within which the grouping of such closely related phenomena as the physical environment, human settlements and economic activity are combined to present some form of unity or whole. The extent of this region, which may be termed the Nottingham Region, is shown by the map on page 34 and it will be seen that its limits are drawn irrespective of administrative boundaries and with little reference to natural features. It might well be termed a cultural region. It includes a section of the Trent valley, about sixteen miles in length, from Long Eaton to a point beyond the village of Hoveringham, with the adjoining territories on either side. That to the north extends as far as Mansfield, embracing the basins of the small rivers Leen and Dover Beck, and is bounded on the west by the Erewash valley. South of the Trent the region stretches to the line of the Leake Hills, on to the high ground of the South Notts. Wolds, and includes part of the Vale of Belvoir. The whole occupies an area of about two hundred square miles and contains about 465,000 inhabitants, nearly 60 per cent of whom belong to the city. The evidence for thus defining the Nottingham Region is provided by a detailed analysis of the geographical conditions and cannot be given in
full here. Within the area, however, are certain well-marked subdivisions which will be described in turn.

**Geographical Setting**

The central unit of the Nottingham Region is, of course, the city itself. Geographical factors, both regional and local, have favoured its growth and development. Among the former is the character of the landscape and in this connection the geological map, inset opposite page 48, presents two striking features. One is the somewhat regular arrangement of no less than seven different types of surface rocks forming belts which converge upon the position occupied by the city, whilst the other is the manner in which the valley of the Trent cuts across this pattern in a northeast—southwest direction. The town originated where the valley touches the Bunter Sandstone, a point towards which other belts of rocks converge, and the present city boundary as fixed in 1932 encompasses portions of the Middle Coal Measures, Permian (Magnesian) Limestone and Marl, Bunter Sandstone and Pebble Beds, Keuper Sandstones and Marls together with stretches of the alluvium and gravels of the Trent. Among other large towns only Bristol perhaps can show a comparable variety of geological formations within its territory. Such a circumstance gives to the locality an unusual diversity of surface features, soils and natural resources.

Nottingham also occupies a marginal position between the uplands of the Pennines represented by the bleak hilly region of Derbyshire and the lowlands which lie to the east. Since the Trent Valley provides an axis of movement from the heart of the Midlands to the Humber, north—south routes developed at an early date, the position of the town became therefore one of more than local importance, for several roads converged upon it in order to cross the river.

Of the local factors concerned in the site of Nottingham the Bunter Sandstone, by reason of its lithological characters and surface topography, exerted a profound influence. The frequent exposures of the buff-coloured sandrock at the roadside, or beneath the walls of the older buildings, or again in the form of bold cliffs as in the Castle Rock give a characteristic touch to the city environment. Numerous caves have been excavated from the sandstone throughout history, and their preservation, in some cases since prehistoric times, illustrates another feature of the rock, i.e., that once excavated by man or even carved by erosive agencies it does not readily crumble or fall away. Advantage is still taken of this fact, for many a sandrock wall in the residential parts of Nottingham has been hollowed out to provide a private lock-up garage. Typical caves occur in the grounds of the University College overlooking the lake. Others are of historic interest, e.g., those of the Rock Cemetery (Mansfield Road) and those at the foot of the Castle which now form part of the remarkable inn known as ‘Ye Olde Trip to Jerusalem’.

The southern extremity of the main outcrop of the Bunter Sandstone terminates in two hills between which is a broad hollow sloping gently towards the Trent. Here is the site of early Nottingham. The hills overlook the flat plain of the Trent by a sharp slope which in parts takes the form of a cliff. This is well seen in the south face of the Castle Rock
and at several points along the Castle Boulevard, or again along Canal Street. Significantly enough this is the only point in the whole course of the Trent from the Potteries to the Humber where its valley is not carved from the red rocks of the Keuper Series. Ancient Nottingham took the form of a dual settlement at first confined to each of the two hillsites, the one reaching to 250 feet, is now occupied by a residential district, the hospital and the Castle; the other rising to not more than 150 feet, contains the Lace Market and St. Mary's Church, the mother church of the city. Between these lay the hollow which eventually became the Old Market Place.

Sketch-map showing details of the site of early Nottingham. Note the alternative route into the town from the Trent. The older road is that which mounted the eminence where the Saxón township first grew and where also St. Mary’s Church was built.

Although there is little surface drainage over the sandstone because of its porosity, much water is stored beneath the surface and was doubtless reached by wells to serve the needs of the early communities. In any case an abundance of stream water was available from the Leen if not
from the Trent. The character of the Bunter Pebble Beds thus played a leading part in determining the site and form of the old town and still provides some of the most typical features of the local environment. Northwards the sandstone outcrop widens to form a belt of territory several miles wide which stretches throughout the rest of the county. The thin dry soil of this region encouraged neither cultivation nor settlement and was accordingly left to support the heath, bracken and scattered woods of oak and birch which comprised much of Sherwood Forest. At one time the forest extended southwards to the gates of Nottingham and to this day a few ancient trees within the city, as at Woodthorpe and Thorneywood, survive as relics of these historic woodlands.

Another local factor of importance was the River Leen. The lower course of this stream, after turning eastwards near Lenton (i.e., Leen-ton), followed closely along the foot of the sandstone cliff for a distance of nearly two miles before making its final turn towards the Trent. Access to Nottingham from the south therefore involved crossing both the main-stream and the Leen, whilst between the two rivers the floodplain was marshy and traversable only by means of an elevated causeway. Thus the town formerly presented a sharply defined and easily defended margin to the south. Parts of the modern city which cover the floodplain here are still known as Broad Marsh, Narrow Marsh and the Meadows. Despite its protective value, the Leen gave direct access to the town for small craft sailing up the Trent, an advantage which served commercial interests from time to time until the age of canals. Recently an old-time landing stage was discovered near the foot of the Castle Rock. The Leen formerly provided sites for watermills which in turn developed into village settlements spaced at intervals of little more than half a mile along the main section of its course. Such was the origin of Bulwell, Basford, Radford and Lenton, all of which have later been absorbed into the body of the city. The marked concentration along the banks of the Leen of bleaching, dyeing and finishing-works connected with the modern textile manufacturing shows how the value of these centres persists.

**Historical Development**

The full significance of the site of Nottingham is more clearly shown, perhaps, if the broad facts of its historical development are outlined. Beyond occasional finds of Bronze Age and New Stone Age implements there is little evidence of human occupation in pre-Roman times, though an ancient salt way which crossed the Trent hereabouts suggests the likelihood of ancient settlement in the District and the practice of moving salt along this route confirms an early recognition of the river-crossing. Whatever the origin of the first permanent community to the north of the Trent in this district, the strategic value of its position in relation to the river and to the sandstone gave it considerable advantage over other sites. Admittedly the nearest Roman station so far identified was at Margidunum, an armed camp on the Fosse Way, near East Bridgford, some twelve miles from Nottingham. The Fosse Way itself at no point between Leicester and Newark approached within five miles of the present position of Trent Bridge, whilst another road, directed towards Little Chester near
Derby, left the Fosse at Vernometum, a station thirteen miles from Leicester. Lying within the fork so formed, Nottingham remained undeveloped and unconnected with the great road system which carried the traffic of the country during the Roman period.

It is unlikely that settlement dwindled however, for by the sixth century Saxon occupation had become firmly established in the region and the foundations of the first township had been laid. The place took its name from the descendants of Snot, i.e., Snotingham, whence Notting-ham, who settled there. The Danish incursions which followed brought a new significance to the place in the ninth century. These invaders penetrated southwards from the Humber and those who made headway up the Trent in their ships found that at Nottingham the river passage converged upon the overland route from York by the Rufford road taken by their brethren. Although the Danes carried their plunder beyond the river, Nottingham became established as the virtual head of navigation, a distinction which, though now of small importance, has been held ever since. The contact of land and water routes was consolidated in the year 924 by the building of the first bridge across the river. The present Trent Bridge dates only from 1871 though it was widened in 1926. At the end of the bridge on the south bank may still be seen one of the many arches of the ancient structure in brick and stone which it superseded.

In Norman times the development of Nottingham took a further turn and there grew into being a dual township involving differences of plan and function which remain to this day among the most interesting features of the city. In addition to the original Saxon quarter, the strategic value of the site was signalised by the building of a castle upon the massive crag half a mile to the west. The Norman fortress not only held the line of the Trent but also dominated the older township and sheltered a rival community. As the two developed, the one with its civil population of Saxon descent and the other a disciplined military centre, their respective interests and activities became sharply divided. There was indeed a strict partition of the territory that lay in a broad hollow between them. This formed a natural meeting ground where markets could be held and was also reached by the road coming from the Trent. Here was established the Great Market Place of Nottingham, the largest open square in the country. (See sketch-map on page 28.) A wall was built at one time to separate the English and Norman markets, a division which is clearly shown in the inset plan on Speed’s well-known map of Nottinghamshire, 1611. Portions of the wall remained until much later but the distinction between the two townships possibly survives to-day in the contrast between the street names of the districts on either side of the square. The Saxon town particularly is recalled by such thoroughfares as Bridlesmith Gate, Hollowstone and Weekday Cross. These are in contrast to such names as Friar Lane, Chapel Bar and Angel Row.

It was only during the latter part of the nineteenth century that Nottingham spread towards the Trent although in 1839 the first railway had been built to the south of the Leen. In the crowded district known as the Meadows will be found Crocus Street, a locality once famous for
its spring and autumn crocuses even outside Nottingham, and it is hard to believe that there are persons still living who remember such flowers growing in the fields there.

**Industrial Nottingham**

Coal, of course, has played a leading part in the industrial development of the region, though certain characteristic Nottingham trades such as metal-working, machine-knitting, brewing and tanning date from times far earlier than the era of steam power. Yet centuries ago coal was obtained from shallow outcrop workings to the north-west of the town in the neighbourhood of Cossall, and at the end of the sixteenth century, for example, coal was bartered for freestone (Inferior Oolite) brought from Ancaster for the building of Wollaton Hall, the fine Elizabethan mansion now serving as the Natural History Museum. Deering, the local historian, writing in 1751 remarks that coal was then the chief commodity exported from Nottingham. Large scale working did not develop until the following century and was naturally confined at first to the vicinity of the Erewash valley where the coal measures appear at the surface. Eastwood, Brinsley, Cossall and Trowell were, therefore, among the earliest mining centres in Nottinghamshire. In 1859 at Shireoaks near Mansfield was sunk the first colliery of the 'concealed coalfield' in which the shafts must first penetrate the cover of Permian and Trias rocks before reaching the coal-bearing strata. The success of this was followed especially between 1870 and 1890 by the sinking of a number of important mines, notably around Mansfield (Kirkby and Sutton-in-Ashfield) and along the Leen valley (Hucknall, Linby and Newstead) towards Nottingham. These developments led to a particularly rapid increase in the size and importance of Mansfield—a growth which has not yet shown signs of abating—and also to a new conception of the richness and magnitude of the Nottinghamshire coalfield.

To the obvious benefit of local industries several collieries were sunk in the immediate neighbourhood of Nottingham, in some cases (e.g., Clifton, Radford and Cinderhill) within the city boundary. The valuable Top Hard seam producing both good steam-raising and 'soft' coal for domestic use and the Deep Hard seam came to be worked by most of the pits, while the High Hazel seam mined at Bestwood and Gedling has become widely known for its excellence as an ashless house coal. In addition to serving the needs of the region a great trade has grown up, chiefly directed by rail towards London and the south, although to-day considerable quantities from the north of the county are moved through the Humber ports.

Apart from coal and good communications it is not easy to account for the growth of the textile trades to such a degree in Nottingham and the surrounding district. Certain fundamental inventions made in the locality played a leading rôle and serve to emphasize the human factor in industrial progress. Lace and hosiery share a common origin in this region for, in a sense, the primitive stocking-frame of William Lee of Calverton was the proto-machine of both industries. Then the long series of inventions and machine improvements connected with the names of
Arkwright, Hargreaves, Hammond, Heathcoat, Mellors, Levers and many others, most of them Nottingham men, served to foster the lace industry in particular to such an extent that the town attained to an unchallenged supremacy which it held until the first decade of the present century. At the time of its heyday before 1910, lace-making employed some 25,000 persons in the city alone, and the houses of Birkin and Simon May had become world renowned. Changes of fashion and foreign competition have chiefly been responsible for the marked decline in subsequent years, though manufacturers have sometimes been able to adapt their products to the changing times. Thus mosquito netting for use in the tropics is now a profitable section of the trade, whilst the use of new materials such as artificial silk has enabled other branches to retain their markets. To a large extent, however, the decline in lace has been offset by the developments in the manufacturing of hosiery, especially since the War, although in this branch of the textile industry Nottingham remains less important than Leicester. Nevertheless, many famous hosiery and knit-wear products originate from Nottingham and district. 'Meridian' (J. B. Lewis), 'Viyella' and 'Day and Night Wear' (W. Hollins), 'Vedonis' (G. Spencer) and 'Flying Wheel' (I. & R. Morley) are outstanding examples, whilst 'Celanese' locknit products and 'Aristoc' stockings from Spondon and Langley Mill respectively are made nearby. Here again manufacturing is accompanied by continual adaptation and specialisation, for the hosiery trade too is becoming increasingly subject to the vagaries of fashion.

In ironworking and engineering, Nottingham boasts a long tradition based no doubt upon the treatment of ore obtained from Derbyshire in mediæval times. Fine examples of early Nottingham wrought iron work are preserved in the Castle Museum, whilst the skill of the craftsmen is commemorated in a couplet which became proverbial:

'The little smith of Nottingham
Who doth the work that no man can.'

The smithies and forges of the old town are represented to-day by workshops and foundries engaged in a remarkably wide range of manufacturing. The best comprehensive term for this is 'light engineering', in which three main branches can be distinguished. There is first the construction of textile machinery, of great importance to the lace and hosiery manufacturers as well as providing for a large export trade. This, of course, is the outcome of a long connection between textiles and engineering and an equally long tradition of local skill and inventiveness. Indeed, it has been claimed that the modern lace-machine is perhaps the most complicated piece of textile machinery ever devised. Then there is the making of cycles and motor-cycles, the names of Raleigh and Brough especially being of universal repute. Thirdly comes a variety of mechanical products, most of which are small though highly specialised in character: typewriters, clocks, telephones, totalisators and other electrical installations; boilers and heating apparatus; small high-speed steam engines for pumps, fans and hydro-extractors, (the sugar extractor is a Nottingham invention dating from 1837); sterilisers and gas-meters.
The manufacture and preparation of chemicals in Nottingham is related in some measure to the demands of the textiles, especially the dyeing and bleaching sections, and other local industries as well as to the abundance of pure water. Like Burton and Newark, also on the Trent, supplies of gypsiferous water have favoured Nottingham as a brewing centre, where also caves and cellars hewn from the local sandstone have proved advantageous.

The leather trade dates from the ancient practice of oak-tanning for which the trees of Sherwood Forest were exploited. To-day, however, as in the case of the large factory at Trent Bridge, the industry is mainly concerned with light and fancy leather-ware made from sheep- and goatskins. Similarly the furniture trade was originally dependent upon the Forest timber and, despite the general use of imported timber by present-day firms, Nottingham still possesses the largest English oak furniture factory. Printing and lithography are also important trades. Brick-making and earthenware, particularly the manufacture of flowerpots, of which there is an extensive overseas export, result from the working of the red marls of both the Permian and Keuper Series. Numerous food products, including beet sugar, add to the diversity of Nottingham's industries.

Special mention should be made of the phenomenal development of three famous concerns. No other establishments have made such progress nor enjoyed such prosperity in recent years and in each case their factory is now the largest of its kind in the world. These are Player's tobacco and cigarette-making factory, Boot's new factory at Beeston for drugs and pharmaceutical products, and the Raleigh cycle works. They employ approximately 7,200, 6,600 and 3,800 workers respectively. The huge size of these units and the universal fame of their products convey a more spectacular impression of industrial Nottingham to-day than many of the older activities.

THE SURROUNDING REGION

Beyond the limits of the city the Nottingham Region includes a number of districts or sub-regions which may be termed in the economic and cultural sense, tributary districts. As these are grouped closely around the city they inevitably feel its influence, yet, because they differ markedly from one another in character, they contribute to the diversity of interests exemplified by the city and, above all, heighten the individuality of the region as a whole. It was one of these districts which gave rise to the frame-knitters of the seventeenth century, who, in turn, laid the foundations of the hosiery industry in Nottingham. Near the same area is Southwell Minster to which the city looks for diocesan care. From another of these districts comes the mineral gypsum, now chiefly worked for cement and plaster, but which in the form of alabaster once brought fame to the Nottingham carvers who excelled in fashioning statuary and small ornaments.

Of the five tributary districts the first lies to the north-east of the city and forms a portion of the low Keuper plateau being drained by the Dover Beck and the still smaller Cocker Beck. This is a picturesque
farming region whose colourful landscape of grassland, tilled fields and orchards, scattered copses and old villages may claim to be the most delightful sample of the Nottinghamshire countryside. As in the case of Southwell, in the neighbouring valley of the Greet, the occurrence of the Waterstones along the valleys provides a good soil, much lighter than the red marl which forms most of the surface. A feature of the stream courses is the small narrow gulleys called ‘dumbles’, e.g., Lambley Dumble, Oxton Dumble, in which the presence of a layer of hard sandstone (skerry) may give rise to a miniature waterfall. Of the half-dozen villages, Oxton is perhaps the most picturesque and least spoiled; nearby are well-preserved earthworks of Celtic origin. Calverton is famous as the home of William Lee, the inventor of the first stocking-frame, and a small hosiery works is still in operation. Many of the cottages here, as in other villages, retain the long multi-paned windows immediately below the roof-line, behind which the stockingers formerly placed their frames.

INDEX MAP TO GREATER NOTTINGHAM
Next is the country extending northwards from the city. Here the surface is formed by the Bunter Sandstone, which is bordered on the east by the Keuper escarpment, a feature of varying prominence, and on the west by the valley of the Leen. The thin, loose-textured, sandy soil and the porous surface give rise to an open rolling country with broad dry valleys. Settlements are few, apart from scattered farms, much of the surface being covered by tracts of heath and bracken, woods and occasional modern plantations, thus providing a foretaste of the conditions prevailing in the Dukeries beyond. There is, however, a spaciousness and breadth of view which, in the absence of towns and villages, makes this relative wilderness attractive. Near Nottingham the wooded estates of Bestwood, Ramsdale and Sherwood Lodge virtually constitute a little Dukeries. At the head of the Leen valley in the midst of a large estate, now unhappily being broken up for building purposes, is Newstead Priory, the ancestral home of the Byron family. The poet’s remains are interred in the church at Hucknall, a small mining town a few miles to the south. The belt of industrialism which extends northward along the Leen valley from the city, spreads out beyond Newstead into a broader zone encompassing the populous areas of Kirkby, Sutton-in-Ashfield, and the approaches to Mansfield. Besides coal, it is from this part of the county that have come so many of Nottinghamshire’s most famous cricketers.

Further to the west is the third of the tributary districts. This is the stretch of undulating country between the Leen and Erewash valleys whose surface is composed mainly of the Magnesian Limestone and the clays and shales of the Middle Coal Measures. The water-parting between these valleys is formed by the somewhat broken and often inconspicuous scarp of the limestone, the eastward dip of which furnishes a gentle slope conveying many streamlets to the Leen. Despite the presence of collieries, much of the land is farmed and several ancient estates survive with their fine old houses of the pre-industrial age, set amidst extensive grounds. Such are Annesley, Beauvale, Watnall, Nuttall and Strelley. Towards the Erewash, however, the productive Middle measures have promoted an intenser degree of industrialism. The course of the Top Hard seam in particular has determined the location of many of the pits, e.g., Selston, Brinsley, Newthorpe, Wollaton. Drab and shapeless settlements straggling one into the other, spread across the coalfield into Derbyshire with scarcely a break between the buildings. The slopes of the valley are in places so comparatively gentle, as at Trowell and Langley Mill, that the succession of mines, factories and houses along the chief roads causes a number of places in Derbyshire to be brought within the commercial and social influence of Nottingham. Ilkeston, Sandiacre and Stanton (the official address of the great ironworks being Nottingham) are instances. Heanor, too, with its textile mills and its large daily traffic of workers travelling to and from Nottingham, is in some respects more closely connected with that city than with Derby.

The mining region is bounded on the south by a reappearance of the Trias plateau. To reach the Trent the Erewash has cut a narrow gap across the northward-facing scarp between Stapleford and Sandiacre. First the Bunter beds and then the presence of resistant ‘skerry’ layers
in the Keuper Marls serve to constrict the valley. Both Stapleford and Sandiacre, centres of lace, hosiery and general manufacturing, are closely connected with Nottingham. Near the former is the Hemlock Stone, a massive erosion feature of great interest, sculptured naturally from the Bunter Sandstone. Below Sandiacre the valley broadens and merges imperceptibly into the Trent plain, where spacious flats furnish the site of the growing town of Long Eaton and the scene of two important railway activities. Of the latter, the Toton sidings, which are among the largest in the country, handle a great proportion of the output from the Notts. and Derbyshire section of the coalfield, whilst Trent Junction is an important focus of main lines and a vital point in the operation of both passenger and goods services on the L.M.S. system. Though administratively in Derbyshire, the town of Long Eaton is linked closely with Nottingham by reason of its industries and transport services. It is the only centre of lace manufacturing of considerable size apart from the city itself, though it has in addition a variety of lesser pursuits. The town has grown from a small centre of 1,600 inhabitants in 1861 to one of 22,000 to-day.

Next comes the vale of the Trent itself, which is at once the most obvious unit of landscape among the sub-divisions of the Nottingham region. In form it resembles a long shallow trench whose sides are generally steep and in places sufficiently abrupt to be termed cliffs, e.g., Clifton, Radcliffe. For a great distance it maintains a more or less uniform width of a mile and a half, whilst over its flat monotonous floor the only exception to the general level is a slight rise of ground here and there not exceeding ten or twelve feet, due to the appearance of older gravel above the alluvium. The present river, though a small stream compared with its prototype, is liable to flood, consequently these slight eminences afforded by single patches or marginal terraces of gravel have played a large part in the fixing of settlements. The villages below Trent Bridge, such as Holme Pierrepont, Stoke Bardolph, Shelford and Gunthorpe, are all situated thus, as well as the older part of West Bridgford itself. Beeston, until recent times, was strictly confined to the limits of a gravel terrace. Serious flooding occurs rarely, though a few fields neighbouring the river are inundated whenever the Trent rises after a prolonged rainy spell. The greatest flood ever known in Nottingham was that of 1875, but that of May 1932 was also widespread and destructive. These and other notable levels are recorded on the embankment wall at the city end of Trent Bridge.

With modern drainage methods and measures to control the river, settlement has spread less precariously over the vale. Not only has the city extended thus, but some of the outlying centres, such as Beeston, Netherfield and Colwick, have done likewise. The process is still going on especially in connection with industrial development. Once freed from the menace of serious flooding, the stretches of meadowland adjoining the river and the railway tracks afford innumerable factory sites. Many recent concerns have been established near to Nottingham in response to these conditions. To the east of the city the Netherfield sidings (L.N.E.R.) utilise the level surface and function as the counterpart of
those at Toton. Further away, the floor of the vale is occupied by farm-
land, about one half of which is arable, largely for market garden produce
destined for the city dwellers or to be despatched by rail. Towards
Thurgarton, near the limit of our region, cultivation decreases and is
replaced by pasture until in the vicinity of Newark the latter preponder-
ates to such an extent that the Trent may be said to flow in a typical
grass vale as was the case before it entered the Nottingham region.

The remaining district to be considered is the southward continuation
of the Keuper plateau across the Trent. This extends for an average
distance of six miles from the river as far as the Rhaetic escarpment
which marks off our region in the physical sense from the Vale of Belvoir
and from the South Notts. and Leicestershire Wolds. Here again the
boundary is arbitrarily drawn, for owing to the insignificance of this
scarp, lines of communication carry the influence of Nottingham to a
greater distance. Thus the villages of Upper and Nether Broughton, the
latter actually in Leicestershire, are brought into close touch with
Nottingham by the well-graded road to Melton Mowbray, though they
are situated nearer to the latter. Similarly the easy routes chosen by both
road and railway to Grantham bring the large village and market centre
of Bottesford to within the economic orbit of the city. The Grantham
Canal, now totally disused, winds circuitously towards the two villages
known as the Cropwells in order to negotiate the scarp with a minimum
number of locks.

The ancient Fosse Way enters our region from the south and, entirely
without reference to Nottingham, strikes across the country with un-
deviating straightness to Newark, where it meets the Great North Road
as the latter crosses the Trent. The Fosse is to-day a good motor road
and now carries a large volume of traffic, particularly since the opening
of the modern bridge at Gunthorpe in 1929 provided an alternative route
to the north, whilst at the same time avoiding Nottingham. Shortly be-
yond the junction of the Gunthorpe road the Fosse reaches territory
which looks definitely towards Newark and which, therefore, cannot be
considered as being tributary to Nottingham.

This section of the Keuper plateau like its counterpart on the other
side of the Trent, is chiefly agricultural country over which are scattered
numerous villages and farmsteads, some of these places, e.g., Radcliffe,
Edwalton, Ruddington and Plumtree, have recently developed as outlying
residential centres of a typically suburban character. Ruddington also
possesses hosiery factories. Bingham, still a large village, was formerly
a market centre for a wide area, and with the Grantham road passing
through it, was once a flourishing township. Other places of note are
Gotham, the home of the legendary ' wise men ', Thrumpton and Cropwell
Bishop which have gypsum mines and plaster works, for the locality
yields considerable quantities of this mineral from the upper layers of
the Keuper Marl. The largest workings, however, are near Newark.
At Tollerton, about five miles from the heart of the city, in the midst of
relatively open country, is the Nottingham airport.

From this sketch of the city and its surroundings it will be seen that
the keynote of both environmental conditions and human activity is
diversity. When William Felkin, the historian of hosiery and lace, addressed the Economics Section of the British Association at its first meeting in Nottingham in 1866 he discussed those two trades which, at the time, certainly promised to occupy the entire energies of the people. Already, he claimed, the town possessed nearly one half of all the bobbin-net machines in the country. To-day, however; it is the centre of a manufacturing district which is now characterised by the wide variety of its products. It is withal an historic city. It has not sprung into existence merely as the result of the industrial progress of the last century and a half; neither has a modern town been grafted to an older one. Rather does Nottingham fall into that group of cities such as Bristol, Norwich and Leicester its near neighbour, in which growth and change have been continuous from the time of an early foundation.

ii. INDUSTRIAL NOTTINGHAM

BY

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The economic character of the City of Nottingham is only to be understood fully when it is treated as the centre of a wider area which may be called Greater Nottingham. It is always difficult to mark out the boundaries of a 'greater' town but various tests can be applied—geographical features, the Census of residences and places of work (1921), the density of the local rail and road services, the location of factories and other works belonging to firms whose offices are in the city, combined with the sense of locality and common traditions or community of social interests possessed by those who know the area well from long living there. These tests indicate that we are approximately correct if we regard Greater Nottingham or Industrial and Commercial Nottingham as including the city itself with the rural districts of Basford (which encircles the city) and Bingham (close in on the east) and the ring of urban districts which adjoin the city directly or are included in or adjoin the rural areas mentioned. These urban districts are Arnold, Carlton, West Bridgford, Beeston and Stapleford (including Chilwell) Long Eaton (just over the boundary in Derbyshire), Eastwood and Hucknall, moving clockwise round the area from the north. Thus Greater Nottingham lies in two counties, Nottinghamshire and Derbyshire, and, being situated at the extreme south-west of an oval shaped county, parts of the area lie near the counties of Lincolnshire, Rutland and Leicestershire. But the area delimited is essentially the Nottingham area, and although most of the urban districts claim rightly to possess their own economic individualities, their people regard Nottingham as their city and recognise the integrity
of the economic life of this area. It is the area approximately of the Labour Exchange 'Nottingham and District' and it is within the Nottingham Postal Area.

The criteria of community of interest referred to above may be applied to show that Nottingham is the centre of a much wider area. Though the interests are more attenuated in the more distant parts they are sufficiently strong to make the people of the county borough of Derby, of the boroughs of Ilkeston, Newark, Grantham, Mansfield and of the interstitial areas regard Nottingham as their main town. In the area marked out by the these towns in the north and west and Loughborough in the south, there is a powerful tradition of unity of economic interests. Each of these boroughs is a centre of economic life and has its own sense of independence and its own traditions, but the nature of their extremely friendly relationships is evidence of their recognition of their close economic kinship.

The unity of this area is of age-old standing; it is due, doubtless, to its geographical nature. The Trent runs through from S.W. to N.E. and the Derwent, Soar, Erewash, Leen, Doverbeck, join it within a short distance of Nottingham, where the best crossing of the Trent was located. The force of gravity brought all its inhabitants into Nottingham—if only for its ancient Goose Fair.

The most significant economic interest common to all the parts of this district—excepting, of course, the ordinary exchange natural to neighbours—is the interest in the textile trade. This area is a real cradle of textile industry: it is doubtful if any other area in the country has such a good claim to the title. Here were born—of pure descent—two textile industries, hosiery and lace, and here took place some of the most important early developments of the cotton trade.

The first hosiery machine (a knitting frame) was made in 1589 at Calverton by Rev. William Lee, M.A. A great framework knitting industry of the domestic type developed from this and the major improvements—Strutts' Derby Rib and the famous Cotton's 'patents'—took place within this local industry. Hargreaves and Arkwright did their early work on cotton in this district and, in 1808, Heathcoat produced his lace-net (bobbin net) machine, followed later by Levers who produced the 'fancy' lace making machine. Calverton saw the first knitting machine; Papplewick saw the first cotton mill driven by power; and Nottingham the first lace machine. At Hucknall, Farrands produced the modified 'jack frame' which is used for the production of Shetland work. Cotton went to Lancashire but there are survivals in the Derwent valley, (Arkwright's) at Cromford, and at Mansfield (Hollins'). Lace has been transplanted to Somerset (by Heathcoat himself) and to Darvel in Ayrshire, but Nottingham still is the lace centre of the country and dominates the trade, while hosiery has spread south and nourishes Leicester, Nottingham sharing the leadership with her.

The second great factor limiting the parts of Greater Nottingham is the coal industry. It has developed chiefly in the western half of the area, in the rich Notts. and Derby coalfield. This field was opened up about 80 years ago—not reckoning outcrop workings—and has had the
effect of pulling the centre of economic gravity to itself. It brought in
its wake iron working and engineering; it dominated the development of
transportation and drew the textile factories and workshops to employ
the daughters of miners. The Erewash and Leen, parallel streams
practically converging on Nottingham, are in mining valleys—two strings
of collieries with a 'knot' at the end, in the borough of Nottingham
itself. There is no iron smelting in Greater Nottingham to-day, but
close by, at Stanton, near Ilkeston, and Butterley, near Alfreton, it
continues with vigour.

Nottingham's industrial activities are not, traditionally, associated only
with textiles and coal. Long before the modern phase of industrialism
developed the area was famed for its handiwork. Pottery, alabaster
work, wrought iron work, watches and clocks and leather were amongst
its products, and the Castle Museum shows a fair number of representa-
tives of some of those trades of early years. And this traditional variety
is her pride to-day. It is a common habit to associate with the name of
a town one or two 'characteristic' industrial products or activities. It
is a facile way of imparting 'economic geography' to children and it
appeals to those who like to describe the results of the 'Industrial
Revolution' in bold, simple phrases such as mass production, localization
of industries, etc. Such a practice describes the actual situation well
enough in some cases but in others it goes wide of the mark. The common
association of Nottingham with lace is a case in point where considerably
less than the truth is conveyed. Nottingham is, in fact, a town of great
variety of industries and always has been, though the proportions occu-
pied in the various industries have changed from time to time. For a
space, lace was very prominent, but for the greater part of her history,
and at the present time in particular, Nottingham was and is much more
than a lace town.

The diagram opposite presents to the eye very clearly the wide distri-
bution of industries in Greater Nottingham by showing its fairly close
conformity to the distribution of industries in England and Wales (Census
classification 1931). On the left side of the vertical line the graph shows
the percentages of working populations (males and females) of Notting-
ham engaged in the twenty-two industries; on the right side is the 'standard
distribution' for England and Wales. Nottingham has certain departures
from the national pattern of industries but the 'distortion' is not great.
Mining, textiles, food, drink, and tobacco, wood and paper industries
are in excess, and agriculture, metals, commerce (and finance) and
personal services are deficient. But all groups are represented in
significant proportions (except fishing!). Some of this variety is the
normal result of being the central town of the area, but to a greater
extent it is the result of her fitting in with the national economic scheme;
her varied industries have national and international markets.

The variety of Greater Nottingham's industries shows itself in every
way, in raw material produced and used, in type of manufactured com-
modity, in stage of production (primary, secondary etc., . . . final or
consumers' goods), in type of organization of manufacturing and market-
ing. She extracts agricultural produce (including sugar beet), coal, clay,
sandstone, limestone, gypsum. She produces beet sugar, milling products, iron pipes and boilers, pottery and bricks, artificial silk; machinery (cycles and textile machines particularly), electrical equipment, telephones, typewriters, textile fabrics (lace, net, lace curtains, warpgoods, embroidery, hosiery, milanese), leather, furniture, clothing (especially women's and children's light clothing), printing, tobacco products and chemicals (heavy and fine) bleaching and dyeing.

This variety of material, product and process (along with the building, transport, commercial, financial and professional activities) has two very important consequences for the area. In the first place there is an outlet for every type of ability, manual, managerial and administrative, technical, scientific and artistic, and there is scope for most kinds of occupational interest. Such variety of occupational possibilities is good for the individual members of the community and it is good for the area itself. Possibly Nottingham's high degree of adaptability to changing economic circumstances, to which we shall refer later, is in some measure related to this.
In the second place the variety of industry contributes to the maintenance of a more or less even keel in passing through the fluctuating economic weather. The mixture of final goods production with primary productions keeps the district from the most violent movements up and down. The recent depression, for instance, has hit Nottingham as it has hit the country, but on the whole Nottingham has probably throughout been on the brighter side of average conditions; her unemployment figures seem to confirm this. Some of her industries and some of the districts within her area have been severely struck, but the fact that in many cases the members of families have been in industries not so depressed has saved the individual domestic situation, and the variety of fortune has saved the area.

There is one rather interesting feature of the balancing of Nottingham's industries which shows itself in the distribution of female labour. The percentage of women in domestic and personal service is only just over half of the national percentage so occupied. The textile, clothing, distribution and clerical demands for this kind of labour are heavy and the Nottingham girls apparently prefer the factory, shop and office to domestic service. The heavy male absorbing industry of mining dovetails with these industries which absorb large numbers of females but, compared with the national distribution of occupations, Nottingham seems to be deficient in available females. It may be that the relative deficiency in heavy metals, demanding males almost exclusively, is a connected circumstance. To some extent there is an immigration of young women from the more distant coalfields of North Notts. and the agricultural districts of the east.

Nottingham's markets are far flung. She has a very large home market for her products but most of her industries have considerable overseas markets too. Her textiles, machinery, telephones, chemicals, and coal go abroad, to Europe, America (North and South), and the Empire. The district is, therefore, like the country as a whole, very concerned about the development of international trade and exchange facilities.

Some of her products are 'fashion' goods. This is to be expected when she is so heavily engaged in textiles and dress. The importance of fashion in the lace trade is, however, probably somewhat exaggerated in the minds of those who are not acquainted with the trade. 'Lace' is not simply lace: it is a group of products and they have different markets. Plain net is a 'bread and butter' commodity with a large overseas (tropical) market. Curtains are furnishings and they have not shrunk in demand to an extent anything like that of lace, the real lace. Lace is a dress material and, since 1914 or thereabouts, the demand has fallen enormously. In the spacious days, it is said, a woman would wear something approaching 100 yards of lace edgings, flounces and insertions on her person at once, but to-day it isn't done! The lace trade has felt this great change in dress requirements but the change from pre-war dress to modern dress is not really fashion. Nevertheless the lace trade does suffer periodic variations; it used to be said in the industry that 'the lace trade followed the iron trade'.
In the matter of organization Nottingham's businesses show some very interesting cases. There are manufacturers, for example, who concentrate all their production in one big factory or works; this is seen in tobacco, chemicals and engineering: there are others who have plants in various parts of the area; this is notably so in hosiery, probably due to the distribution of female labour in the mining districts. Again, in the lace trade there is one large firm which conducts all the processes from the yarn to the market, while the general practice is for the lace makers to sell their produce to warehousemen or merchants, and these latter, after having certain final processes carried through, put the goods into the market. There is an amazing variety of organization in this trade, almost every process being worked to some extent in independent businesses and to some extent in conjunction with others. Nottingham is the 'lace market' and the manufacturing is done there, at Beeston and other places on to Long Eaton. Further, some of the large businesses of Nottingham are branches of 'national' businesses, some even of international concerns; some produce to distribute in their own shops, in Nottingham and elsewhere, Messrs. Boots being the outstanding example. The sizes of businesses also vary; the characteristic size is probably small though the area has many very large ones indeed. In textiles the variety of size is striking, some manufacturers owning two or three machines only.

There is one industry which, in its organization, is almost a survival: the Shetland industry. Here the usual practice is to produce on a hand frame—a modification of the stocking frame. Now-a-days a manufacturer has a factory holding a number of these frames, a dozen or more, and he sells the product to a warehouseman, though it is only a few years ago that a man would have a frame of his own and work for a manufacturer or warehouseman himself. A very interesting practice in this trade is that of the framework knitter producing the new designs: it is said that he used to do this on Good Friday or Easter Monday. The trade has in some ways the flavour of a century ago though in recent years it has extended its products from the old shawls and falls to various other articles of ladies' dress unthought of then.

A passing reference was made above to the power of adaptation which Nottingham has shown in her economic life. It might be better described as initiative. That she possessed it at the end of the eighteenth and the beginning of the nineteenth century is clear from the history of the textile trade. Felkin, in his 'History of Machine-wrought Lace and Hosiery' gives a vivid picture of the sizzling enthusiasm of the Nottingham frame-smiths and framework knitters experimenting with a hundred and one machines to produce a lace fabric. They were in hot pursuit for years before Heathcoat succeeded. And when this was done the same restless spirit of the area pursued improvements and modifications of all the various lace and hosiery machines: always it sought for something new.

But not only in technical inventions were Nottingham's textile men alert: they showed the same energy and driving power in business organization and great firms were born then that still stand: Birkin, I. & R. Morley and others. As time passed on, this technical and business dynamism continued to show itself in the textile trade and has done so
to the present day. New firms have risen and grown strong, and old firms have adapted their activities to new conditions. New fabrics have been produced, new raw materials introduced, and new modes of utilizing them have been developed. There is no slavish persistence in rendering one service because this one service has always been rendered. Firms producing lace have entered the 'making-up' trades—a form of vertical integration—and firms using one fabric of their own production buy fabrics of other trades to join them in supplying a new market demand.

Textiles, however, have not claimed all the initiative of the town. Men of enterprising character and great ability have been spread over the varied field of industry and the town has reaped a variegated crop of fine industrial flowers. The great organization of Boots, the famous Raleigh Cycle Works (using Bowden Brakes and Sturmey Archer Gears), Player's Tobacco Factory, Barlock Typewriters, Beeston Boilers, Stanton Ironworks, are some of the outstanding examples of Nottingham enterprise, and there are many others in the electrical, machine building, motor, tanning industries. They are all firms which have either originated new products or have, with the expanding market demand of recent years, taken the lead by virtue of efficiency.

In a dynamic economic system new industries grow and, inevitably, certain old industries languish or shrink, for dynamism means a changing pattern of activities, a changing allocation of resources, not simply the addition of fresh activities. Nottingham has seen a certain amount of such shrinkage, dynamic shrinkage, shrinkage due to economic 'progress'. We have noted one of these already; there has been since the beginning of this century, a change in the part played by lace in dress and Nottingham has had to accommodate herself to this change. In coal, also, there has been a change and surplus miners, like surplus lace workers, have had to move into the expanding trades. This many have done, though there is a 'hard core' of unemployment which is accounted for by this change.

Besides the native growth of new industries certain new ones have migrated into the area or have been developed by men from elsewhere. Outstanding examples of this incursion are Ericsson's Telephones (Beeston) and Celanese (Spondon). In addition there has been a development in Nottingham and at Chilwell of activities connected with the arming of the country.

In the great industrial changes of the last generation Nottingham has, then, maintained her traditional dynamic character. She has adapted her old industries to new demands, she has developed new industries or made small ones grow larger, and she has attracted to herself businesses from elsewhere. After the earlier industrial revolution she took her place on the south of the great industrial north, active in a variety of ways. In the new industrial revolution she is again taking her place on the north of the new industrial south. Again she is distributing her interests and occupations, hoping to ensure thereby the condition of steady prosperity which, all things considered, has been her good fortune hitherto.
III.

NOTTINGHAM DISTRICT

i. THE GEOLOGY OF THE DISTRICT

BY

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P. E. KENT, B.Sc.

INTRODUCTION

The area covered by this survey includes Nottinghamshire and the adjoining portions of Derbyshire, Leicestershire and Lincolnshire. It forms a compact physical unit limited on west, south and east by the high grounds of the Derbyshire hills, Charnwood, the uplands of Leicestershire Wolds and Lincoln Cliff respectively. On the north it is bounded by the Humber Carrlands and the marshy ground around the lower reaches of the Trent and its tributary the Idle. Seven gaps in this ring of physical barriers give access to the country beyond. The gateways of the Middle Trent and Soar lie between the Charnwood upland and the Derbyshire Hills on the one hand and the Leicestershire Wolds on the other. The valley of the Witham crosses the boundary twice and in doing so has given rise to one exit south of Grantham and another at Lincoln. Between these lies the almost dry valley of the Sleaford Gap. In the north are the gateways of Bawtry and the Rother, lying between the Derbyshire Hills and the marshlands of the Idle, and separated from one another by the rising ground of the Permian limestone.

The geological formations which underly this area and its boundaries are as follows:—

Glacial and Post Glacial deposits:

Mesozoic.

Inferior Oolite.
Lias.
Trias.

Palaeozoic.

Permian.
Carboniferous.

Precambrian.
Charnian.

In the northern part of the area the outcrops of these formations follow a north to south course, but as they approach the latitude of
Nottingham they curve and converge towards one another (see map inset opposite page 48) with the result that half the formations are to be found within the city boundaries. As the Mesozoic rocks continue westwards they cover up the outcrops of the Palaeozoic rocks south of the latitude of the city. 

H.H.S.

**CARBONIFEROUS**

The Carboniferous rocks of Derbyshire exhibit in their lithology a three-fold division of Limestone, Grits and Coal Measures which reflect in the contrasting soils, vegetation and land forms three very characteristic types of scenery.

The dominant structural feature of the region is the Pennine anticline of which the Derbyshire Dome forms the southern termination. The prevailing easterly dip of the Carboniferous strata is broken by subsidiary folds marked by inliers of limestone at Crich and Ashover, and further minor folds occur in the Coal Measure basin to the east, constituting the southern part of the Yorkshire, Derbyshire and Nottinghamshire Coalfield. The fact that these folds when traced southwards develop a Charnian trend suggests that older trend lines were re-emphasized by post-Carboniferous movements.

**CARBONIFEROUS LIMESTONE**

The Carboniferous Limestone dome of Derbyshire is perhaps the most visited area of ‘Mountain Limestone’ in the country. The subdued topography of the limestone plateau is accentuated by the deeply notched dales, whose streams are, as in the days of Isaac Walton, still famed for their fishing, and no visit to the district could be deemed complete without seeing Dovedale or some other such scenic gem of Derbyshire.

The massive crystalline limestone is of considerable purity and exposures in natural river cliffs, caverns, railway cuttings and extensive quarries facilitate a closer study of the rock.

With the exceptions of a small area of limestone near Buxton which may belong to the upper half of the Seminula zone (S₃) the 1,500 feet of limestone exposed are of the Dibunophyllum zone (D). On the whole the upper beds are of darker hue and are more silicified than the lower and the former are also the more fossiliferous. *Lonsdaleia floriformis*, *Lithostrotion* of various species and other reef building corals are succeeded by gigantic productids. The grey crinoidal ‘marble’ is in evidence in many a Derbyshire mantelpiece and in the paving of corridors and quadrangle of Nottingham University College at University Park the stone from Hopton Wood quarry has been used with effect.

A feature of the Derbyshire dome is the evidence of contemporaneous vulcanicity in the form of lava flows (the ‘toadstone’ of the lead miner), bedded tuffs and associated necks of agglomerate. In addition there are sills of Olivine dolerite of somewhat later date which together with the ‘toadstones’ have been quarried for road metal. The mining of lead ore in Derbyshire is of great antiquity and the laws governing the working of galena and the associated gangue minerals in the Wapentake of
Wirksworth are of more than antiquarian interest. Fluor spar, barytes and calcite are the normal gangues and the 'Blue John' variety of fluor from Castleton takes pride of place as a Derbyshire mineral specimen.

Millclose Mine in Darleydale has been worked continuously since 1861 and though other mines are worked intermittently it would appear that most of the ore above water level has been extracted. To-day the abandoned mines and natural caverns penetrated by the workings are an attraction to the tourist rather than of interest to the miner. The extensive soughs, driven during the last century in an attempt to de-water the mines, provide an abundant water supply though in quality hardly to be compared with that from the succeeding Millstone Grits, on which the fame of Matlock Spa depends.

**Millstone Grit**

The scenery of the Gritstone country is in striking contrast to that of the Limestone dome; heather moorland and edge-like escarpments take the place of the grassy rounded forms of the limestone plateau.

The streams of the grit-country tumble over the successive grits in a succession of waterfalls and the early development of the textile industry in Derbyshire was based on the water power thus provided. Moreover the water from the grits is as 'soft' as that from the limestone is 'hard' and the hydropathic hotels of Matlock and the bleachers and dyers find this pure gritstone water ideal for their requirements. The Derwent Valley Water Scheme has made these waters available to Sheffield, Derby, Nottingham and Leicester and such a supply will prove a big factor in the future development of the East Midlands.

The so-called 'Limestone Shales' below the Millstone grit are now considered to belong to the Upper Carboniferous and rest unconformably on the limestone in Derbyshire. In the shales of the Edale valley in North Derbyshire, J. H. Jackson has found in descending order goniatites characteristic of the lower Reticulocerus sub-zone, the Homocerus zone and the upper sub-zone of Eumorphocerus but the absence of the goniatite *Eumorphocerus pseudo-bilingue* and the associated marine fossils suggests that the lower sub-zone of the Upper Carboniferous is unrepresented in Derbyshire. The Edale shales are succeeded by the Mam Tor sandstone and Shale Grit series or the Fifth Grit of some authors, and this is followed by the Grindslow Shales which so far have yielded no fossils. The Kinderscout or Fourth Grit attains its maximum development in North Derbyshire and is characterised by a lower coarse and often conglomeratic leaf separated by shales from a finer grained and often flaggy upper division. In common with other grits the Kinderscout contains casts of plant stems usually so ill preserved as to defy precise indentification.

The Middle Grits include the Belper or Chatsworth Grit and the Coxbench Grit. These grits often occur in wide courses and the Coxbench in particular has provided building stone of exceptional tensile strength and weather resisting qualities. The intervening shales are seldom exposed. As in the case of the Upper Kinderscout, each of these grits is immediately overlain by underclay and a thin coal seam. Though
these coals are of little economic importance as such, they frequently prove of value to well sinkers as an indication of the presence of the underlying water-bearing stratum.

The Rough Rock or First Grit is perhaps the most persistent of the gritstones and as this coarse grained grit is unusually felspathic it appears more prone to disintegrate, on weathering, than other grits in the series.

**Coal Measures**

Considering the long history of the Derbyshire Coalfield the dearth of literature other than publications of the Geological Survey on the Coal Measures is surprising.

In 1312 coal was being mined at Cossall on the Nottinghamshire and Derbyshire border and locally mined coal probably played a part in driving Queen Eleanor from Nottingham Castle as early as 1257. The local product has long since lived down this unfortunate incident and to-day no two coals are more esteemed than ‘Derby Brights’ and ‘Nottingham Ashless’.

In Derbyshire, where the measures are fully exposed, the mining engineer has hitherto been satisfied to depend almost entirely on lithology for purposes of correlation of seams, but in Nottinghamshire where the measures are largely concealed beneath an unconformable cover of Permian and Triassic strata the need for palaeontological indices has been recognised and marine bands and more recently non-marine lamellibranch zones have here proved of value as aids to correlation.

The productive measures of Derbyshire and Nottinghamshire do not exceed 3,000 feet as compared with 5,000 feet in Yorkshire, and the difference in thickness is accounted for by the relative absence of massive sandstones in the southern portion of the field. Here argillaceous shales and clays predominate and are extensively quarried for bricks and coarse pottery.

In Derbyshire the lower seams, particularly the Kilburn, Low Main or Furnace, Deep Hard and Deep Soft in ascending order, have been and still are the backbone of the mining industry though thinner seams are now being economically worked. In Nottinghamshire the Top Hard (Barnsley of Yorkshire) and the associated seams in the upper half of the Middle Coal measures are proving even more profitable.

Whereas the ‘Visible Coalfield’ has been exploited for more than 700 years and many collieries are finding it increasingly difficult to maintain an economic output, the working of the ‘Concealed Coalfield’ only dates back to 1859, and to-day in Nottinghamshire large collieries with all the advantages of modern equipment and vast resources of accessible coal are capable of an output far in excess of present consumption.

This inland field has from the first been mainly concerned with the home market and though during the post-war years there has been increased competition with other fields which had re-entered the home market on the decline of their export trade, the local field has been fortunate in that new collieries have been put into successful operation even during the darkest years of the depression.
The outstanding problem of the Concealed Coalfield is the possible extent of the field eastwards beyond the River Trent. A recent boring at Harby, within six miles of Lincoln, points to the probability of available reserves of coal in Lincolnshire and in some measure confirms the optimistic findings of the Royal Commission of 1905. Borings at the south of the present field and the out-cropping of Millstone Grits at Castle Donington and Carboniferous Limestone in the Ticknall and Breedon inliers show that there is little possibility of any considerable extension in a southerly direction. The present tendency towards cooperation amongst mining enterprises in the Concealed Coalfield is leading to the more rapid solution of many minor structural problems within the field and though the Geological Survey Memoir on the Concealed Coalfield of Nottinghamshire and Yorkshire (G. V. Wilson, 1926), is still in substance correct, new developments in mining and fuel research have added to our knowledge of the field within the past decade. The Mansfield Marine Band at some distance above the Top Hard seam has proved the most valuable index horizon in the Concealed Coalfield and in the wider correlation of coalfield with coalfield since a corresponding datum has been recognised in Skipsey's Marine Band of Scotland and in the Cefn Coed Marine Band of South Wales.

The Non-Marine Lamellibranch fauna has proved amenable to zonal divisions and in the productive measures of Nottinghamshire and Derbyshire a definite zonal sequence has been determined.

The lower limit of the Similis-Pulchra zone is immediately below the Top Hard seam and that of the Modiolaris zone has been fixed with some precision below the Deep Hard group of seams. The Low Main is the highest seam of the Ovalis zone, which zone extends downwards to the horizon of the Kilburn seam which is, in effect, the base of the productive measures of this field. The equivalence of the Kilburn seam of Derbyshire and the Arley seam of Lancashire has now been recognised (Wray, 1936) and the Lenisulcata zone extends downwards into the Millstone Grits.

The upper limit of the Similis-Pulchra zone and an attenuated Phillipsii zone are known only in borings and shaft sections in the Concealed Coalfield, where the red unproductive measures of the upper zone are found in an area south of the Mansfield-Newark line, which direction marks the Charnian trend of the Brimmington Anticline under the Permian-Trassic cover.

It is one problem to speculate on the probable extent of the Concealed Coalfield and another to sink shafts through the water-bearing sandstones of the overlying strata but that is a problem for the mining engineer rather than for the geologist. The application of a cementation process during sinking has been successful in recent enterprises. The effects of mining subsidence on the water undertakings on the overlying sandstone are being watched with some anxiety by water engineers and the city of Nottingham is fortunate in having a reserve supply from the Derwent Valley Scheme.

S.G.C.
### Permian and Trias

The following subdivisions of these systems may be recognised in this area:—

<table>
<thead>
<tr>
<th>Permian</th>
<th>Trias</th>
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<tr>
<td>Marl</td>
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<td>Magnesian Limestone.</td>
<td>Sandstone.</td>
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<td>Marl Slates.</td>
<td>Basement Beds.</td>
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<td>Breccia.</td>
<td>Bunter.</td>
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<td></td>
<td>Conglomerate.</td>
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<td></td>
<td>Sandstone.</td>
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Towards the close of the Coal Measure period, earth movements took place which resulted in the conversion of this area along with the rest of the country into dry land, and the establishment of an elongated dome-like uplift in the region of North Derbyshire, and of less prominent folds trending from north-west to south-east. These folds defined the western and southern limits of the great synclinal basin of the Derbyshire and Nottinghamshire coalfield. At the same time extensive denudation took place and produced a varied landscape with limestone uplands, millstone grit and coal measure sandstone scarpers separated by broad valleys in the belts of shale and clay.

It was upon this very diversified surface that the Permian and Triassic rocks were laid down, a fact which accounts for innumerable idiosyncracies in the form and distribution of the outcrops of the latter.

### The Permian

The Permian rocks are exposed in the northern outskirts of the city, where they have a total thickness of about 60 feet.

The unconformity which they make with the underlying Coal Measures is emphasised by the presence of a layer of breccia at the base. This has a maximum thickness of about 8 feet near to Mansfield. From thence it spreads out in fan fashion towards the north, east and south thinning out as it does so until in a distance of about fifteen miles it is represented by only a coarse grit.

The Marlslates are thinly bedded earthy magnesian limestones separated by bands of shale, and sometimes crowded with very fragmentary plant remains. The classic exposure in the Kimberley railway cutting which was first described by Edward Wilson is still the best place to see these rocks.

The magnesian limestone is abundantly exposed in the quarries at Bulwell on the northern side of Nottingham. It is made up of clearly defined beds of various thicknesses. Unlike the rock as seen near Mansfield, where it is compact and fine grained, it here consists of dolomite crystals which are large enough to give it the appearance of a coarse sandstone. At the outcrop recognisable fossil are rare, but in the boring further east brachiopods, bryozoaa, ostracods, and encrinite ossicles have been found.

The Permian marl consists of a deep red or chocolate coloured marl
interbedded with layers of magnesian limestone in its lower and beds of sandstone in its upper portions. The latter are frequently lenticular in section as though they had been deposited in current channels excavated in the clay from time to time during its formation. The marl is overlaid by fine grained red sandstone which is usually classed as Bunter. There is, however, no clear boundary between the two, for the sandy beds just mentioned have the same characteristics, whilst the lower portions of the sandstone contain much clay both in the substance of the sandstone itself and as films and layers interbedded with the sandstone. Traced southwards the Permian thins away rapidly and disappears in the western outskirts of the city.

It is worthy of note that Edward Wilson, who was a very careful and cautious observer and had unique opportunities for examining exposures, would not refer these lower sandy beds to either the Permian or the Trias. In 1876 the Geologists Association visited this district and in the report of their visit they state quite emphatically that the passage from the Marl to the Bunter is 'perfectly continuous'. After the lapse of twenty years and the examination of many new exposures local geologists see no reason for altering this description.

THE TRIAS

The Bunter Sandstone or Lower Mottled Sandstone is well exposed at a number of points on the western side of the city. It is predominantly red in colour with lines and patches of yellow and greenish yellow. It has a fine grain and in its lower portions contains so much clay that it constitutes a good moulding sand used both for iron and bell founding. These lower parts are usually well bedded often with layers of clay and sometimes strings of angular pebbles. The upper portions on the other hand are usually false bedded.

The Bunter Conglomerate is predominantly current bedded though occasionally well defined strata may be seen. They are coarse grained and yellow though patches of red fine-grained sand occur. Pebbles are always present sometimes scattered sporadically through the rock, at other times concentrated in the bottom portions of the current channels. A very large proportion of the pebbles consist of quartzite ranging in colour from light grey to dark red, and in rare instances they have yielded fossils. The remaining pebbles form a mixed assemblage including vein quartz, lydian stone, Torridonian sandstone and various kinds of volcanic rock. In this district they rarely exceed three inches in length. Clay boulders nine inches or a foot long form an interesting feature in pits where the rock is being excavated for use in mortar and plaster. The outside of these is coated with small pebbles picked up by the clay as it was rolled along by the currents. The junction of the conglomerate with the Lower Mottled is often a sharply marked irregular line, and constitutes the first clearly marked break from the Permian breccia upwards.

The Bunter as a whole varies greatly in thickness. This rises to a maximum of more than 600 feet north of Mansfield. From thence it also spreads out fanwise becoming thinner as it passes north, east and south. Southwest of Nottingham it is 200 feet thick and at Dale it has
diminished to only 40 feet. The form of the rock mass suggests that of a supra-terrestrial delta with its axis pointing to the north-west as the direction of origin of the material.

The top surface of the Bunter is wind eroded and carries irregular heaps of loose pebbles, many of which are facetted. Facetted stones have also been found in the bottommost beds of the Bunter where it rests upon the old landsurface, as for example at Dale.

The Bunter outcrop occupies one quarter of the area of Nottinghamshire and is an invaluable source of water supply for all towns within a reasonable distance of its boundaries.

The Keuper Basement Beds in the vicinity of the city of Nottingham vary in thickness up to 16 feet. Here they consist of sandstone having the same texture as the conglomerate but almost white in colour. In this state they appear to be a marginal or shore facies for they change as they pass eastward into finer grained sandstones of light grey colour interbedded with red marls, having a total thickness, a few miles to the east, of 40 feet.

The Keuper Sandstone has a clearly defined base marked by the presence of a thin conglomerate—the Keuper conglomerate. This passes up into a bed of yellowish sandstone some 3 feet thick. This division of the Keuper is 100 feet thick and is made up of clusters of interbedded sandstones and marls from 20 to 30 feet thick separated by a corresponding thickness of red marls. The sandstone belts exhibit a marked rhythmical repetition from thick layer of sandstone through thinner beds with beds of marl to thicker beds of marl. The surfaces of the sandstone layers vary in character and exhibit ripple marks, rainprints, suncracks and footprints. On three occasions they have yielded fish remains belonging to species of *Semionotus* and *Woodthorpea*.

The Keuper Marl has a thickness of 600 feet and consists mainly of red marl with occasional belts of thinly bedded fine grained sandstone known as 'skerry'. The marl varies in character slightly. Some layers are compact and appear to show no lamination. Others strikingly resemble varve clays in all but colour. The skerry often shows curly bedding but sometimes the surfaces may be ripple marked or may bear crowds of salt pseudomorphs. Toward the top of the Keuper marl gypsum appears in sufficient quantity to be mined. In its uppermost portions the marl becomes green and is then known as the Tea-green marls.

H.H.S.

**THE JURASSIC BEDS**

Jurassic beds outcrop over a broad belt in the East Midlands. The greater part of the sequence is present, and only the Portland and Purbeck beds do not occur in this area.

The strike of the beds is N.N.W. in the north of Lincolnshire, N. in mid and south Lincolnshire, and changes to S.W. in Leicestershire and Northamptonshire. The alternation of hard and soft rocks, dipping gently eastwards, has given rise to a series of escarpments. Thus the marlstone gives rise to the Belvoir escarpment, and to the high ground
near Tilton. The Inferior Oolite forms the long, straight Lincoln edge and the scarp near Rockingham, and the thinner limestones overlying that form minor ridges.

The light soils of the limestone outcrops are much used for agriculture, but the heavy clays of the lower land are now mainly devoted to pasture. The distribution of water-bearing beds has exercised a marked control over the location of villages, particularly in Lincolnshire.

During the last century, wide use has been made in the Fens of artesian water from the Lincolnshire Limestone, which provides the most important water-bearing beds in this part of the area.

The ironstones of the Lower Lias are worked at Frodingham, and that of the Middle Lias Marlstone is extensively exploited in Leicestershire. The Inferior Oolite Northampton Ironstone is worked in Northamptonshire, south of Grantham and at Lincoln.

At the close of the Triassic desert period the greater part of the East Midlands became submerged beneath a sea in which the marine Jurassic deposits were accumulated.

The first were the Rhaetic beds, which maintain constant characters throughout the area. The lower part consists of 15-20 feet of black shales, which yield Pteria contorta, Schizodus and Protocardia. Local thin sandy bands occur crowded with fish teeth. The upper Rhaetic usually consists of 10-20 feet grey-green marls, with scattered limestone nodules, which yield Estheria. Thin ripple-marked sandstones sometimes occur. The White Lias, which forms the highest part of the Rhaetic in the south of England, is unrepresented here.

The Lower Lias consists mainly of clays, with secondary limestone bands in the lower part. In Leicestershire the Blue Lias or Hydraulic Limestones correspond to the Angulatum and Bucklandi zones, as in southern England. The beds below are poorly represented. Further north the Hydraulic Limestone series is of planorbis and preplanorbis age, and the overlying Angulatum and Bucklandi zones are clayey. The limestones have yielded an interesting fauna, including insects, corals, saurians, fish and crustacea at Barnstone and Barrow-on-Soar.

In North Lincolnshire a bed of oolitic iron ore, 30 feet thick, known as the Frodingham ironstone, occurs in the Lower Lias. The base of this bed yields Coroniceras, cf. gmuedense, the middle part contains abundant Cardinia and Gryphaea, and during a recent visit to Scunthorpe Aegasteroceras, cf. saggitarium (Blake) and Eparieties colenotii (D'Orb.) (identified by Dr. Spath) were obtained from the upper part. The ironstone is therefore a greatly condensed deposit, representing 200 feet of beds in the south, for the lower beds belong to the early Bucklandi zone, and the upper part to the Stellare zone. In South Lincolnshire a thin ferruginous limestone is the only lithological representative of this bed, and the presence of Arnioceras belonging to the Bucklandi zone in the overlying clays shows that the greater part of the ironstone has passed laterally into clay.

The upper beds of the Lower Lias are grey shales and clays, which at Old Dalby have yielded a very rich fauna of ammonites, belemnites, gastropods and brachiopods. At Bracebridge, near Lincoln, the beds
of the Davoei zone contain abundant well preserved capricorns, and inflated ammonites of the Liparoceras type. A thin ironstone band occurs at this level in North Lincolnshire.

The lower part of the Middle Lias (Margaritatus zone) consists of grey clays, occasionally sandy, with ironstone nodules. The beds measure nearly 100 feet in Leicestershire, 56 feet at Grantham, 30 feet at Lincoln, and probably thin out a little more farther north. The Spinatum zone is represented by the marlstone ironstone, which may be as much as 40 feet thick. The ironstone is well developed north and south of Melton Mowbray, but it is very thin north of Market Harborough and is absent for 15 miles north and south of Lincoln. It is noticeable that where the marlstone is attenuated Dactylioceras has been recorded (Ingham, Leadenham, and north of Market Harborough), showing that the attenuation is due to the failure of the lower part of the bed. The fauna of the ironstone includes Lbothyris punctata, Tetrarhynchia tetrahedra, Pteria inaequivalvis and Belemnites elongatus. The zonal ammonite is very rare. Locally a thin bed with Tiltoniceras and dactyliocerates occurs at the top of the ironstone.

The upper Lias consists of 100-200 feet of dark shales and clays with scattered nodules. Study of the fauna shows that the lower beds are thickest at Lincoln, the middle beds reach a maximum at Grantham and the upper beds are best developed in Northamptonshire. The fauna shows a mixture of Yorkshire and southern forms. Various species of Harpoceras and Dactylioceras are common.

Resting nonsequentially on the Upper Lias is the Northampton ironstone, 10-20 feet thick, a green oolite ore which weathers to a brown ferruginous sand. It has been shown that the material forming this bed came from a land mass southeast of Kettering. Unlike the Lias ironstone, this bed is usually unfossiliferous, but Lioceras spp, Hinnites velatus, Trigonia spp. and various brachiopods occur at certain places. In North Lincolnshire this ironstone is represented by 2 feet of ferruginous sandstone, which has recently yielded brachiopods of scissum age. The Northampton Ironstone is succeeded nonsequentially by the Lower Estuarine Series, a variable thickness of pale sands and clays with vertical plant remains. Determinable fossils are almost entirely absent from these beds.

The most important member of the Inferior Oolite Series is the Lincolnshire Limestone, which first appears at Kettering and thickens to a maximum of 140 feet south of Grantham. The greater part of the limestone is oolitic, but raggy beds occur locally in the upper part, and in North Lincolnshire the lower part of the formation passes into a cementstone series (the Kirton Beds). At the base of the limestone, near Stamford, are thin sandy beds, which yield siliceous flags known as Collyweston Slates. These beds are overlapped towards the south. Ammonites have shown that the base of the limestone is of discites age, and brachiopods indicate that the whole of the Bajocian and part of the Vesulian are represented by the limestone. The various epiboles maintain a constant thickness as traced along the outcrop, and the variation in thickness of the limestone depends almost entirely on the amount of pre-Bajocian denudation.

P.E.K.
GLACIAL AND POST GLACIAL DEPOSITS

The late Dr. Bernard Smith aptly described this area as a ‘cockpit where tongues of ice from various directions strove successively for territorial rights’. Just beyond its eastern and southern margins considerable areas of boulder clay occur consisting of material brought by ice moving southwards over Lincolnshire and westwards across Rutland into Leicestershire. Projecting northwards from the Leicestershire Wolds is a spur capped with boulder clay which reaches almost to the Trent. This seems to have marked the position of the terminal moraine of that selvage of the ice which flowed along the Vale of Belvoir.

North and west of the Trent only scanty fragments of boulder clay are to be found and these are confined to the higher grounds. The most obvious and at the same time the most southerly of these lies on a series of high points stretching from Blidworth almost to the city boundary. Magnesium limestone occurs in the boulder clay throughout the area. On the eastern side, chalk and oolite are recorded, but on the west these are replaced by boulders from the more resistant portions of the carboniferous rocks. Stone of more distant origin have come from the Whinsill and the Lake district.

Though boulder clay is scanty, gravels abound. The higher level gravels spread like outwash sheets on both the Bunter and Keuper outcrops, and their soils yield numerous facetted pebbles.

The valleys of the Trent and its tributaries have been excavated out of the surface upon which these gravels were spread, and in them are found the lower level gravels. The oldest of these occupies a prominent terrace which extending from University Park westwards through Long Eaton to Borrowash. Fragments of a terrace of the same age occur along the south side of the valley at various points from West Bridgford to Newark. At Beeston these gravels have yielded early palaeolithic implements.

The floor of the major part of the main valley lies about 40 feet below the surface of this terrace. On it lies a sheet of gravel of variable thickness and irregular surface. The more upstanding portions of this are still to be seen rising above the level of the alluvium, thus providing the sites for many of the villages in the vale between Nottingham and Newark. These gravels have from time to time yielded tusks and teeth of the Mammoth at various points as far down stream as Hazelford thus proving that this part of the floor of the valley must have been formed during the ice age. These gravels contain numerous flint fragments which must have come from the chalky boulder clay on the country south of the Trent.

Since the deposition of these lowest gravels the river has been occupied mainly in filling up the hollows on their surface with resorted gravel and alluvium. During the early stages of this process some of the hollows were occupied by extensive sheets of standing water which in course of time became filled with peat. This in its turn was covered with alluvium. One such body of water remained until the University College buildings in University Park were erected. This water occupied the site of the western end of the present lake in which it was subsequently incorporated.
When the lake was being extended deposits of peat of considerable thickness were found around its margins and bronze age implements were brought to light.

H.H.S.

THE PHYSICAL FEATURES OF THE AREA

Between the peneplained plateau of the Derbyshire limestone massif, with its surrounding grit moorlands, and the floor of the Trent valley are to be found traces of successive stages in the physiographic evolution of the area. At each stage no doubt, as now the major features were scarps and vales whose arrangement was determined by the distribution of the more and the less resistant rocks as seen upon the geological map. Generally speaking the crests of the scarps to-day preserve traces of the older peneplains, whilst the later phases of change have been most marked along the vales, which have been progressively deepened, with a consequent emphasising of the scarp features.

Along the southern flanks of the Pennines distinct evidences of an erosion surface occur at about 700 feet. This surface appears to sink eastwards and to reach a level of about 550 feet in the Mansfield plateau. Another and more extensive surface, which has developed at the expense of the higher one, sinks from a level of about 450 feet at its fringes along the foot of the Charnwood hills, the Ashby plateau and the edges of the 700 foot surface, to a level of about 300 feet near the course of the Trent. This erosion surface represents a portion of the pre-glacial Trent basin, and is the surface upon which rest some of the boulder clays and most of the out-wash gravels of the area. Into this surface was etched, during late glacial times, the present system of rather narrow and moderately steep-sided valleys of the Trent and its tributaries.

H.H.S.

ii. THE CLIMATE OF NOTTINGHAMSHIRE

BY

K. C. EDWARDS, M.A.

The broad features of the climate of Nottingham such as the comparatively great range of temperature and the comparatively slight rainfall, much of which occurs during the summer half-year, are materially influenced by its inland position. The city itself is situated more than one hundred miles from the west coast and is further sheltered to some extent from westerly maritime influences by the uplands of Derbyshire and north Staffordshire. The east coast at Skegness is almost seventy miles away, though this distance by no means prevents cold easterly winds from sweeping across Lincolnshire to Nottingham and the middle Trent valley.
Local factors of altitude, slope and shelter, of course produce slight yet noticeable differences of climate within short distances. Thus both the temperature and rainfall conditions prevailing at Mapperley, an elevated and somewhat exposed suburb, (400 ft. O.D.) sometimes differ considerably from those met with in the lower and more sheltered parts of the city, (90-100 ft. O.D.). Doubtless, too, the Trent valley exerts some influence upon meteorological phenomena in the region, though so far little systematic observation has been attempted in this connection.

Historical

At the meeting of the British Association in Nottingham, 1866, it was generally felt that extended meteorological observations especially as to temperature and rainfall were needed and that they should be conducted as far as possible with instrumental and practical uniformity. Accordingly a station was established in Nottingham which has been maintained without interruption up to the present period. So runs the preface to a pamphlet published in 1879 entitled 'The Meteorology of Nottingham, 1867-78', which was a collection of readings taken by M. O. Tarbottton, the Town Surveyor of the time. Needless to say the local station referred to continues its observations and in the meantime several others have come into being.

Before the time of Tarbottton, however, little interest was taken in meteorology as far as Nottingham is concerned. Among the earliest records is 'A Meteorological Register kept at Mansfield Woodhouse in Nottingham' from the beginning of 1785 until the end of 1794. This was published in 1795 and contains records of wind directions and the number of days in each month on which frost, snow and rain occurred. Its compiler, Hayman Rooke, proffers the naive and disarming apology: 'I do not pretend to offer this as a philosophical register; such an undertaking would have required a stationary residence which I could not conveniently submit to'. To Robert Lowe's well-known 'Survey of Nottinghamshire Agriculture', published in 1798, are appended rainfall figures for several years recorded by W. Thompson, a resident of West Bridgford. A real pioneer, nevertheless, is found in the vigorous person of E. J. Lowe of Beeston who, in 1853, published 'The Climate of Nottingham during the Year 1852', an historic document in the annals of local meteorology. It is of special interest to recall that most of Lowe's observations were made during his forty years' residence at Highfield House which stands only a few yards from the recording instruments now in use at University College. In addition to this publication, Lowe made a careful study of local rainfall conditions and prepared the first records of monthly means.

Later, at Hodsock Priory near Worksop, Colonel H. Mellish commenced observations and established a fully-equipped station which continues to keep records. Local meteorology is profoundly indebted to Colonel Mellish. His rainfall map of Nottinghamshire (and accompanying paper) was published in the Q. J. R. Met. Soc. 1893, and on his decease in 1927, through the kindly offices of the Meteorological Society, his valuable collection of works on meteorology and climatology passed to the library.
of University College. More recently, Mr. Arnold B. Tinn of Nottingham has presented to the library of the Royal Meteorological Society an exhaustive collection of climatological data relating to the city, extending over a period of twenty years and including many items not usually available. Mention should also be made of the chart illustrating the principal meteorological conditions on each day of the year in Nottingham prepared annually by the City Engineer and Surveyor. This document, with its clearly printed details is of inestimable value in the study of local conditions.

**Temperature**

Temperatures in Nottinghamshire are affected by the inland situation of the county and by its location eastward of the Pennines, for both circumstances prevent a full development of westerly maritime influences. The absence of mountains within the county itself and the comparative evenness of relief make for a marked uniformity of temperature conditions. The whole area has a mean temperature of slightly under 38° F. for January, whilst in summer there is little more than one degree of difference between the extreme north of the county (July mean 61° F.) and the extreme south (July mean 62.1° F.), a distance of over 50 miles.

In detail, too, there is a close similarity between the average monthly mid-temperatures of the four stations given below.

**Mean Monthly Mid-Temperatures (1881-1915) in F°**

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Belvoir Castle, of course, lies beyond the county boundary in Leicestershire. This similarity occurs in spite of the differences in altitude between these stations and the only appreciable difference is that in summer as might be expected, the city is slightly warmer than the stations situated in the open country. During the two months June and July the mean temperatures for Nottingham (Trent Lane) are 0.5° and 0.6° respectively above those for Hodsock Priory, whilst for all the remaining months of the year the difference is less than one-half of a degree.

The moderating influence of the sea is naturally not felt so much as in regions nearer the coast, consequently the mean annual range of temperature (about 22° F. for Nottingham and 22.9° F. for Hodsock) is considerable. This is exceeded, however, in many districts of eastern England, e.g. Cambridge, where the range is 24° F. Throughout the county and adjoining regions January is the coldest month with a mean of 37.5° F. and July the warmest with a mean of 60.5° F. August is but one degree cooler than July. The relative weakness of westerly in-
fluence must not be pressed too far regarding temperature, for in winter, west and south-west winds often blow, as elsewhere, with characteristic mildness and raise the temperature several degrees. Prolonged cold spells, on the other hand, are not uncommon owing to the establishment of anticyclonic conditions over the continent resulting in the drift of easterly winds across the North Sea.

**Pressure and Winds**

In the absence of data for local stations the following table giving the mean monthly barometric pressure for Derby, situated only 16 miles from Nottingham, should be of general interest, though of little practical value in making a detailed study. Day-to-day changes are of course vastly more important.

**Mean Monthly Atmospheric Pressure at Derby in Inches**

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<td>29-900</td>
<td>29-917</td>
<td>29-860</td>
<td>29-932</td>
<td>29-969</td>
<td>29-955</td>
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</tbody>
</table>

Weather conditions in Nottinghamshire, as in all parts of the British Isles, are largely governed by the prevalence of westerly winds throughout the year. The following table shows the average number of days in each month experiencing winds with components from the four cardinal points of the compass at Nottingham.

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<td>7</td>
<td>5</td>
<td>86</td>
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<td>E.</td>
<td>4</td>
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<td>S.</td>
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<td>5</td>
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<td>5</td>
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<td>52</td>
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<td>W.</td>
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<td>15</td>
<td>17</td>
<td>14</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>172</td>
</tr>
</tbody>
</table>

Computed from daily readings published in the annual reports on the meteorology of Nottingham, for the period of thirty-five years, 1891-1925.

Winds with a westerly component thus blow during 172 days, i.e. nearly half the total number of days in the year. They are felt on at least 12 days in every month and are most frequent in January and August and least in April and May. Similar observations made at Hodsock Priory over a period of 30 years (1876-1905) show that west and south-west winds together prevail there for almost one-third of the days in the year.

Northerly winds blow during nearly one-quarter of the days of the year and predominate in April and May when there is a weakening of the westerlies. Easterly winds are commonest in April and May, though at Hodsock they are most frequent in March. Southerly winds, though less frequent than those from other quarters, blow during a uniform number of days each month. The table deals only with the average monthly occurrence of the various winds and conveys no idea of their strength or of the length of time they prevailed. True calm days, i.e. days on which no movement of the air is recorded at the time of observation, are seldom experienced and these have been disregarded in com-
piling the table. On the other hand, since only seven such days were
recorded in Nottingham during the selected period of 35 years, it is
obvious that the gentlest drift of air has been recorded throughout as a
wind.

Of great interest are the observations made by Mr. A. B. Tinn, whose
exhaustive analysis of local climatic data has been mentioned, indicating
the mean maximum temperatures accompanying winds from different
directions. Thus, over a period of 20 years, the maximum air temper-
ature reached with a south-westerly wind in the month of January is as
high as 47° F., but is only 36° F. with a north-east wind.

Humidity

Detailed figures for the relative humidity of the atmosphere are not
available for stations in Nottinghamshire, though Cranwell in Lincoln-
shire (some 28 miles east-north-east of Nottingham) is one of the twelve
stations selected by the Meteorological Office to represent the normals of
this element of the weather. There are many occasions during the
course of a year when the conditions of humidity at Cranwell
approximate closely to those at Nottingham.

As with all the other stations, Cranwell shows a high humidity prevai-
ing during the autumn and winter months. This reaches a maximum in
December during which only for a short period daily, i.e. for an hour or
two following midday, is the humidity under 90%. No station, however,
not even Valencia or Eskdalemuir, experiences such a long period of
persistently high humidity, and the autumn period as a whole provides a
higher humidity throughout the day at Cranwell than at any other station.
Similarly, no station records such a high average maximum humidity
(more than 96%) as occurs in the early mornings, 3 a.m. till 7 a.m., in
March. Humidity is lowest, as at most places, during the early after-
noons of the summer months. At Cranwell however, where it is under
68% in May and July, it is never so low as at Kew (58%) or at Lympne
(64%) in July.

The mean annual range of humidity is normally greater in the eastern
districts of the British Isles than in the westernmost parts, and greater at
inland stations than at the coast. Consequently Cranwell, like Notting-
ham, having an eastward interior situation, shows a considerable range,
actually twice as great as that of Valencia.

Rainfall

The rainfall map of Nottinghamshire (inset opposite page 62) has been
constructed from the records of 53 stations within the county, the great
majority of which possess readings complete for the standard period
1881-1915 and are distinguished in 'British Rainfall' as first class stations.
The map published by H. Mellish in 1893 was based upon the records of
only nineteen stations within the county though as many as forty from the
adjoining counties were used. Though most of the latter possessed records
extending over a period of thirty years, usually for the period 1861-90,
a number of them were subject to discrepancy owing to the use of in-
different instruments and even the occasional removal of a rain-gauge to
another site. For guidance in completing the present map twenty stations situated outside the boundaries of the county have been used.

The rainfall over the county is comparatively slight, ranging from 22 inches to 30 inches per annum. In general the amount decreases from west to east, i.e. from the high ground along the borders of Derbyshire to the lowlands of the Trent. The greatest amount, i.e. over 30 inches, is found upon the small stretch of high ground reaching to 600 feet between Sutton-in-Ashfield and the Derbyshire border, while the highest mean total is that recorded for Hardwick Hall (31.8 inches) which lies just beyond the county boundary. There is, moreover, a very gradual transition from the moister to the drier parts of the county. Relief features naturally influence the amount of rainfall and provide some noteworthy local differences. Thus the high ground at Redhill and Dorket Head (500 ft.) lying to the north of the city receive nearly two inches more per annum than the surrounding district. Mapperley, a part of Nottingham rising to over 400 ft., receives one inch more than the neighbouring quarters of the city which are less elevated. Especially marked is the Belvoir Castle ridge, lying outside the county to the south-east, which is indicated on the rainfall map by the enclosed 25 inch isohyet. Similarly the larger valleys are somewhat drier. An important feature of the map is the long tongue of relatively dry territory, not shown on previous rainfall maps of Nottinghamshire, following the Trent valley and traced out by the 23 inch isohyet. This is explained by the general flatness of the vale in contrast to the more broken and elevated country out of which it has been carved. Locally within this tongue are small areas with a mean annual figure of under 22 inches. Such are Lowdham (21.4 inches), the lowest figure for the county, and Sutton Bonington, near which is the Midland Agricultural College (21.7 inches).

The map further indicates that from the well-watered uplands near the western border rise the streams which feed the chief rivers draining to the Trent. The Erewash and Leen together with the headstreams of the Idle all commence in territory over which there is an average rainfall of more than 27 inches.

Nottinghamshire then, with the greater part of its surface receiving less than 25 inches of rain per annum, forms part of the relatively dry region of eastern England, though it should not be described as lying within the 'rainshadow' of the Pennines. For purposes of comparison the following is a selection of mean annual rainfall totals for stations in other centres of the East Midlands:

<table>
<thead>
<tr>
<th>Station</th>
<th>Altitude in feet</th>
<th>Rainfall in inches</th>
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<tbody>
<tr>
<td>Derby (Arboretum)</td>
<td>196</td>
<td>26.2</td>
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<tr>
<td>Loughborough</td>
<td>135</td>
<td>23.1</td>
</tr>
<tr>
<td>Leicester</td>
<td>266</td>
<td>24.2</td>
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<tr>
<td>Grantham</td>
<td>188</td>
<td>24.1</td>
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<tr>
<td>Newark</td>
<td>43</td>
<td>23.4</td>
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<tr>
<td>Lincoln</td>
<td>58</td>
<td>22.8</td>
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These centres, all of which are comparatively low-lying, show a marked similarity in their respective totals.
Mean Monthly Rainfall at Nottingham (Trent Lane, 82 ft. O.D.) in Inches.

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<td>1.74</td>
<td>1.45</td>
<td>1.59</td>
<td>1.34</td>
<td>1.80</td>
<td>2.28</td>
<td>2.40</td>
<td>1.56</td>
<td>2.39</td>
<td>1.81</td>
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Mean reduced to 30-day month

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<td>1.68</td>
<td>1.55</td>
<td>1.54</td>
<td>1.34</td>
<td>1.74</td>
<td>1.85</td>
<td>2.20</td>
<td>2.32</td>
<td>1.56</td>
<td>2.31</td>
<td>1.81</td>
<td>2.23</td>
<td>2.25</td>
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No. of rainy days*

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<td>11</td>
<td>16</td>
<td>14</td>
<td>18</td>
<td>167</td>
</tr>
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</table>

*i.e. days on which 0.01 inch or more is recorded

Rainfall, as the above figures show, is distributed uniformly through the year, there being a difference of but slightly more than one inch between the mean for the driest month (April, 1.34 inches) and that for the wettest month (August, 2.40 inches). Although October is commonly the wettest month and autumn the wettest season in most parts of Britain, a considerable quantity of rain is received during the summer months at Nottingham. Thus July and August are distinctly wetter than any other two consecutive months, and as much rain falls during the summer half-year (April-September, 11.23 inches) as during the winter six months (October-March, 11.28 inches). Indeed, for some stations, though by no means all, August is definitely the wettest month, e.g. Nottingham (Trent Lane), Beeston. At the Trent Lane station the three summer months, June, July and August, account for 29% of the total for the year, a greater proportion than for any other three consecutive months although the combined amount for October, November and December is but a fraction less.

The tendency towards a summer maximum was first demonstrated in the case of Nottingham by E. J. Lowe as early as 1890 though it is now widely recognised in other parts of eastern and east-central England. It is explained by the occurrence of convection showers and also by rains which accompany thunderstorms associated with local secondary depressions. These develop frequently in the afternoon or early evening during the summer months.

The first four months of the year are all relatively dry and May brings more rain to all parts of the county than any preceding month. September provides a notable respite in the sequence of somewhat rainy months and incidentally allows time for surface drainage to proceed, otherwise, owing to the configuration of the county, much land in the neighbourhood of the Trent would readily become waterlogged, as indeed may happen after prolonged rains at any time of the year.

The average number of rainy days in the year at Nottingham is 167 and these too are distributed evenly through the months. Those with fewest rainy days are June and September, whilst December has the greatest number. It will be observed that, apart from October, the months of maximum rainfall are not those with the greatest number of rainy days, for the latter are related rather to the frequency of travelling ‘lows’. Thus December and January, being the months of maximum cyclonic activity, have more rainy days than any other two consecutive months.
THE CLIMATE OF NOTTINGHAMSHIRE

The chief features of the rainfall of Nottinghamshire are therefore, its comparatively slight amount, its tendency to occur largely during the summer half-year, and its marked uniformity of distribution throughout the county. With regard to the last it may be said that fully two-thirds of the total area receive a mean annual amount varying between 22 and 25 inches.

The occurrence of snow in Nottinghamshire is restricted as a rule to a few days each year. The Book of Normals (Meteorological Office) gives the average number of days upon which snow falls at Sheffield as 25 per annum, but at Nottingham the average is probably less, i.e. in the neighbourhood of 18 or 20 days. These occur chiefly in the first three months of the year. Snow rarely stays long, though upon the high ground near the western borders of the county it may linger for a longer period than elsewhere.

Sunshine

The mean daily amount of sunshine received by the Midlands area as defined for meteorological purposes is 3.82 hours. Nottingham, with an average of 1,325 hours per annum, receives slightly less, i.e. an average of 3.63 hours daily, an amount which, nevertheless, compares favourably with Sheffield (3.61 hours) and Birmingham (3.11 hours). Experience suggests, however, that for much of the year the daily quantity of sunshine at Nottingham is slightly above the average for the region, for during the late autumn it is undoubtedly reduced by the prolonged periods of fog and mist which are unfortunately characteristic of that season. Indeed, the figures for the six months April-September are considerably above the average, but following September with its 4.20 hours daily duration there is a rapid falling off in the amount of sunshine, the October average being only 2.68 hours and that for December as low as 0.90 hours. There is rarely, however, a dense smoke pall over the city.

At Hodsock the mean daily sunshine amounts to 3.43 hours which is less than at Nottingham. There is the same liberal quantity during the summer and a similar decrease in October due not only to the renewal of stormy and cloudy conditions but also to the proximity of the mining and industrial district extending from Worksop into south Yorkshire. These figures, though comparatively poor when contrasted with those for the sunnier districts of the south, compare favourably with those for the adjoining uplands of Derbyshire and the more industrial parts of Yorkshire. Belvoir Castle, however, despite its altitude (259 ft.), has the much better daily figure of 4.21 hours and this may be regarded as representative of much of the rural territory of south Nottinghamshire.

May is generally the sunniest month throughout the county though locally, as at Hodsock, the daily mean for June is slightly higher, whilst often the figures for July and August are but a fraction lower. In summer the Lincolnshire coast, with its promise of abundant sunshine, draws large holiday crowds from this region, and Skegness, popularly known as ‘Nottingham-by-the-sea’ boasts of daily means of 7.0 hours for June and more than 6 hours daily in May, July and August.
THUNDER

In the Nottingham district as with the Midlands in general, thunder occurs chiefly during the summer months. It is commonly associated with small secondary depressions which develop locally during the afternoon or early evening. Records kept by Mr. A. B. Tinn show the average dates of the incidence of the first and last summer thunder in Nottingham to be 2nd April and 26th September respectively. Two aspects of thunderstorm occurrence in our region provide scope for further enquiry. In the first place E. G. Bilham has pointed out that Belvoir Castle experiences a greater frequency of thunder than any other station in Britain for which data are available, and it appears likely, therefore, that this district of the East Midlands may be the scene of maximum thunder activity for the whole country. Then also attention should be drawn to the behaviour of thunderstorms in relation to their local distribution. No records are yet available but repeated observations point to a tendency for such storms to occur in the neighbourhood of the Trent valley and even to move some distance along it. Rarely does a thunderstorm break over the city itself.

Fog

Though mainly due to cloudiness, the low average figures of sunshine duration for the months November, December and January are partly to be explained by the occurrence of mist and fog. Cold mists persisting for several days frequently give a dreary aspect to the weather throughout the Nottingham region at this time of the year. Dense fog is an unpleasant and sometimes dangerous phenomenon to which the locality appears especially liable. The circumstances of such a visitation vary from a widespread and impenetrable blanket causing serious dislocation of traffic and a toll of accidents, to a number of scattered patches grotesquely localised in the hollows or in the vicinity of the river. Industrial smoke and the existence of cold still air over the damp flats of the Trent valley are undoubtedly among the leading factors in the formation of these fogs. On the occasions of widespread dense fog, however, high ground and lowlying land suffer alike.

CONCLUSION

An English county such as Nottinghamshire is too small a territory in which to find great differences of climatic conditions, and as we have seen, small local differences occur mainly as the result of variations in altitude and aspect. As far as human beings are concerned the conditions are healthy though by no means genial and tend to be somewhat rigorous in winter. In general, the conditions favour agriculture and good grain crops characterise the farming over much of the county. Occasional extremes in precipitation, however, seriously affect the yield of crops on the two main types of land. Drought soon causes difficulty on the light sandy soils of central Nottinghamshire and results in low yields of wheat and barley, poor crops of roots, and even failure in the case of potatoes. On the other hand, prolonged rains are troublesome to the heavy clay lands of the eastern and southern parts of the county. Keen winds and late cold spells in spring sometimes retard the growth of crops especially
in the districts of light soils. Mr. Makings of the Midland Agricultural College has shown that the weather conditions during April and May are of vital importance to arable farming on such land. The rainfall during this critical period should amount to at least 3 inches and should be accompanied by mild temperatures. The mean at Hodsock Priory, situated in the sandy region, for this period is 3.14 inches, though there are many years when the actual quantity recorded is under 3 inches.

Though severe frosts occur in winter from time to time, on the average, four-fifths of the occurrences of ground frost at Nottingham are recorded between November and mid-April. Mr. A. B. Tinn gives the average dates of the incidence of the first and last frosts at Nottingham as 19th October and 19th April. Consequently this factor of climate in Nottinghamshire does not generally hinder the cultivation of the typical farm crops of eastern England.

![Mean Temperature Graph]

**Mean Temperature**

![Mean Sunshine Graph]

**Mean Sunshine**

![Mean Rainfall Graph]

**Mean Rainfall**

**Nottingham (Trent Lane 85 ft. O.D.)**
iii. THE BOTANY OF NOTTINGHAMSHIRE

BY

J. W. CARR, M.A., F.L.S., F.G.S., F.R.E.S.,

EMERITUS PROFESSOR OF BIOLOGY, UNIVERSITY COLLEGE, NOTTINGHAM.

The history of Nottinghamshire botany begins with the publication in 1650 of the *Phytologia Britannica* by William How, but only three species are here recorded for the county, on the authority of Mr. Stonehouse. These are *Dianthus deltoides*, *Antennaria dioica*, and a grass which was probably *Melica nutans*. Although seen by later observers these are all now apparently extinct in the county. In 1666 Christopher Merrett, in his *Pinax*, adds *Sparganium minimum* and a white-flowered form of *Galeopsis versicolor*. These were probably found by Thomas Willissell, who travelled extensively in search of plants and is known to have visited Nottingham about this time: he was the first botanist to observe *Silene nutans* on the walls of Nottingham Castle. The great naturalist John Ray was visiting his friend and co-worker Francis Willughby at Wollaton Hall in 1670 and noticed many Nottinghamshire plants, among which were *Silene nutans*, previously discovered by Willissell, *Cerastium nudicaulis*, *Verbascum pulverulentum* and *Apera spica-venti*. No further additions of any importance were announced until the publication, in 1738, of Deering's *Catalogus Stirpium*, etc., or *Catalogue of Plants naturally growing . . . . about Nottingham*.

Charles Deering, M.D., was born in Saxony, probably in 1695, and after graduating in physic at Leyden came to England and practised for some years in London and elsewhere. He settled in Nottingham in 1736, and died there in 1749; he was buried in St. Peter's churchyard. The *Catalogue* enumerates some 840 flowering plants, ferns, mosses, fungi, etc., but includes some cultivated plants, while a few were erroneously indentified and others are unrecognisable or are unimportant varieties of other species.

A few additional Nottinghamshire plants are recorded by R. Pulteney in a paper on the rarer plants growing about Loughborough, published in Vol. XLIX of the *Philosophical Transactions* and repeated in Nicol's *History and Antiquities of the County of Leicester* (1795).

The first four decades of the nineteenth century were notable for a remarkable activity in botanical investigation in the county, and no fewer than three important works on the Flora of the county were published during this period. The first to appear was the *Flora Nottinghamiensis* of Thomas Ordoyno, issued in 1807, which comprised the flowering plants and ferns, and included many species unknown to Deering. Of still greater importance were the works of Jowett and Howitt.

Thomas Jowett was born at Colwick near Nottingham in 1801, and practised as a surgeon in Nottingham: he died in 1832 at the early age
of 31. In 1826, when only 25 years old, he published in the Nottingham Journal under the pseudonym of 'Il Rosajo' a series of 'Botanical Calendars' or 'Notices of Native Plants of the County of Nottingham, arranged according to the order of their appearance'. These Calendars, twenty-eight in number, appeared at frequent intervals from March to December, and give localities for 1,023 species of flowering plants and cryptogams, including more than 100 not mentioned in the works of Deering and Ordoyno. They received warm commendation from the leading botanists of the period, including Sir W. J. Hooker and Sir J. E. Smith. Four folio volumes of dried specimens of Nottinghamshire plants collected and mounted by Jowett are preserved in the Bromley House Library in Nottingham, and are particularly valuable as settling the identity of several species which are not now to be found in the county.*

Godfrey Howitt, M.D., the friend and co-worker of Jowett, was born in 1800, and after graduating at Edinburgh, practised as a physician in Nottingham. In 1839 he emigrated to Australia and died there in 1873. His Nottinghamshire Flora appeared in 1839 and records 1,137 species of flowering plants and ferns, mosses, hepatics, lichens and algae. As a record of our flora at a period when it was still comparatively unchanged by modern industrial developments Howitt's Flora is, together with Jowett's Calendars, of the greatest value to present-day botanists. Previously, in 1833, Howitt, in collaboration with William Valentine, a talented Nottingham bryologist, had commenced the publication of a work entitled Muscologia Nottinghamiensis, consisting of dried and mounted specimens of local mosses with descriptive text. Three fasciculi, each containing eight species, were issued, but the work then came to an abrupt termination.

A long period of stagnation followed this early activity and during the next half-century only a few additional species were recorded in various botanical works and periodicals. In 1906 however, a great advance was made on our previous knowledge in the article on 'Botany' in the Victoria History of Nottinghamshire by the present writer. In this work, 854 species of flowering plants and ferns were enumerated as growing wild in Nottinghamshire, including a considerable number of interesting species not previously known to occur in the county. The relation between the distribution of our plants and the geological structure of the county was described, and lists given of the species characteristic of the various geological formations. Very many additions were also made to Howitt's list of mosses and liverworts as the result of several years' assiduous collecting; but the greatest advance was made in the fungi, chiefly as the result of the work of the members of the British Mycological Society in Sherwood Forest in September 1897, which resulted in the addition of no fewer than 250 species, mostly of the larger fungi, to our list, as well as the confirmation of a large number of species recorded by the earlier botanists. Many others were found by the writer in the Nottingham

*A full and critical account of this herbarium is given in a paper by J. W. Carr in the Trans. Nottingham Naturalists' Society for 1906-7.
district in the two or three following years, and the account of the fungi contained in the Victoria History represents our present knowledge of the group, with the exception of an article on the Myxomycetes of Nottinghamshire published in the Transactions of the Nottingham Naturalists' Society for 1910–11.

A comparison of the county flora in its present state with the records of Jowett and Howitt furnishes melancholy evidence as to the large number of interesting plants which, once common, have now become exceedingly rare or altogether extinct. The enormous extension of the city of Nottingham and other towns and villages in our area has covered some of our best collecting grounds with buildings; while the cultivation of waste lands, the drainage of marshy ground, the multiplication of railways and collieries, the conversion of large areas of arable land into pasture, and even the laying out of golf-courses, have all been potent agents in the destruction of our native plants. Perhaps the most famous of our disappearing species (though of course not a true native) is the purple spring crocus (Crocus vernus) which formerly covered many acres of the Nottingham meadows with such a luxuriant growth as to suggest the idea of its having been sown as a crop. Most of the ground this beautiful plant occupied is now built over, and though it still persists in a very restricted area, it seems doomed to early and complete extinction. In the same locality grew abundantly the autumnal crocus (C. nudiflorus), first recorded as a British plant in 1738 by Deering, and still to be found there in recent years. The Nottingham Catchfly (Silene nutans) was still common on the ruined walls of the old kitchens of the Castle up to 1889, but the restoration of this part of the Castle in that year destroyed it. It is probable, however, that the plant still lingers on the inaccessible parts of the Castle-rock.

The drainage of the few small areas of bog which formerly existed in the county is responsible for the extinction of a number of interesting plants. Such are the Royal Fern (Osmunda regalis), Lastrea uliginosa and L. oreopteris, the Sundew (Drosera rotundifolia), Cranberry (Oxyccocus quadripetala), Vaccinium vitis-idaea, and the beautiful Gentiana pneumonanthe. On the other hand the rare Crested Fern (L. cristata) still persists in its ancient station, along with the Marsh Fern (L. thelypteris) and the Crowberry (Empetrum). The Bog Orchis (Epipactis palustris), Bladderwort (Utricularia vulgaris), Butterwort (Pinguicula vulgaris), Cnicus pratensis, and Crepis paludosa, long supposed to be extinct, have been rediscovered, each in a single station. The Sweet-gale (Myrica gale) also maintains its footing in a single locality, while the Grass of Parnassus (Parnassia palustris), Bog Pimpernel (Anagallis tenella) and the Cotton-grasses (Eriophorum vaginatum and E. angustifolium) may still be found.

Other interesting plants which formerly occurred but have not been seen for many years are Viola lutea (probably an error of identification), Dianthus deltoides, Moenchia erecta, Radiola linoides, Geranium sanguineum, Cicutta virosa, Myrrhis odorata, Bupleurum rotundifolium, Antennaria dioica, Pyrola minor, Rhinanthus major, Rumex pulcher, Spiranthes spiralis, Cephalanthera ensifolia and C. grandiflora, Orchis
usulata, Stratiotes aloides, Scheuchzeria palustris, Carex digitata, Melica nutans, Hordeum europaeum, Ceterach officinarum, Cystopteris fragilis and three species of Lycopodium. Turning from this melancholy list of probable extinctions it is a pleasure to note that a fair number of species which have always been rare in the county still persist. Among these are Myosurus minimus, Ranunculus parviflorus, Aquilegia vulgaris, Hypericum montanum, Sagina nodosa, Geranium lucidum, Arabis glabra, Lotus tenuis, Sium latifolium, Dipsacus pilosus, Inula squarrosa, Campanula pala, Monotropa hypopitys, Sanolus valerandi, Galeopsis dubia, Littorella uniflora, Rumex maritimus, Ophrys apifera and O. muscifera, Narcissus pseudo-narcissus, Convallaria majalis, Gagea lutea, Spangani minimum, Acorus calamus, Schoenus nigricans, Carex pseudo-cyperus, Calamagrostis epigeios, Apera spica-venti, etc. Moreover a number of truly native species which were unknown to, or not distinguished by, the earlier Nottinghamshire botanists have been discovered in recent years: e.g. Ranunculus lingua (discovered along with Lathyrus palustris at Misson by Mrs. Sandwith and her son Mr. N. Y. Sandwith), R. lenormandi and several Batrachian Ranunculi, Corydalis claviculata, Viola stagnina and several other species, Polygala dubia and P. serpyllacea, Stellaria neglecta, Ulex gallii, Medicago deuticulata, Lathyrus palustris, Agrimonia odorata, Callitriche stagnalis, C. obtusangula and C. truncata, Epilobium adenatum, E. angustifolium (now an excessively abundant and pernicious weed), Carum segetum, Selinum carvifolia, Arctium majus and A. minus, Arnoseris minima, Gentiana baltica, Melampyrum cristatum, Mentha alopecuroides and other species, Polygonum laxiflorum, Rumex limosus, Platanthera chlorantha, Orchis praetermissa, Polygonatum multiflorum, Potamogeton coloratus, P. falcatus, P. cooperi, P. friesii and P. interruptus, Scirpus fluitans, S. tabernaemontani and S. maritimus, Carex canescens, C. binervis and C. fulva, Agrostis nigra, Glyceria plicata, Bromus erectus, many Rubi and Roses, a few Hieracia, Willows, etc. Several new species of Chara and a Nitella have also been found.

A remarkable occurrence so far from the sea is that of Aster tripolium which was discovered in August 1905 by the warping drain near Misson, in company with Scirpus maritimus. This warping drain is connected with the Trent near Owston, and as the river is tidal for many miles above this spot it may well be that the presence of these two maritime plants is due to natural causes. On the other hand the North American Mimulus langsdorffii is an escape from cultivation which attracts the attention of the most casual observer by its abundant, large and showy flowers: it is becoming naturalised in many places in the northern part of the county. Another North American introduction, not seen by any of the earlier Notts. botanists, is Matricaria sueveolens, a shabby-looking weed which has extended so rapidly in recent years as to be abundant in waste ground all over the county.

The number of flowering plants and vascular cryptogams recorded as native or fully naturalised in Nottinghamshire is about 860, but this does not include any of the numerous so-called ‘species’ into which such plants as Viola arvensis, Alchemilla vulgaris, Euphrasia officinalis, etc., have recently been subdivided: many of these occur with us, but have
not yet been fully worked out. Much work also remains to be done among the Rubi, Roses, Hieracia, etc., the forms of which—elevated to specific rank—swell the lists of some of the neighbouring counties. Compared with such counties as Derbyshire, Yorkshire and Lincolnshire our flora must necessarily seem poor, but the reason for this is to be sought in the comparative lack of variety in the physical conditions of Nottinghamshire combined with the highly cultivated state of most of its area. There is scarcely any uncultivated ground with the exception of parts of Sherwood Forest, and this being situated on the dry and arid Bunter sandstone possesses only a poor and scanty flora: even in the wooded parts of the forest the undergrowth consists almost entirely of bracken. There are few or no large sheets of water save the trimly-kept artificial lakes in the principal parks, and there is an almost complete absence of bog, so that lacustrine and bog-loving plants are largely wanting. Moreover, the Carboniferous, Jurassic and Cretaceous limestones which bear so rich a flora in the neighbouring counties do not extend into Nottinghamshire, and their absence is only partially compensated for by the Permian Magnesium limestone which occupies the western margin of the county and, while possessing a moderately rich and varied flora, cannot compare in this respect with the more highly calcareous Chalk, Oolite or Mountain Limestone of the counties around us.

West Yorkshire, with an area of 2,760 square miles, is more than three times the size of Nottinghamshire, and with its numerous hills, many of which are over 2,000 feet high, possesses an extensive alpine or true mountain flora which could not exist with us—our greatest elevation being only 651 feet; moreover the 'pavements', terraces, and scars of the Mountain limestone region, and the wide expanses of moorland and peat-bog, are tenanted by numerous species which for lack of suitable conditions are absent from Nottinghamshire. The same remarks apply in a lesser degree to Derbyshire, which possesses a considerable number of montane plants on its high northern moorlands; the flora of its limestone dales also is a very rich and varied one. Lincolnshire, with an area greater even than that of West Yorkshire, with its long coast-line, its salt marshes, its chalk wolds and Jurassic limestones, has an enormous advantage, botanically, over Nottinghamshire, and it is not surprising that its flora is numerically so much richer than that of its inland neighbour. Leicestershire has a slightly smaller area than Nottinghamshire, with a very similar flora, except that the Archaean rocks which form the high ground of Charnwood Forest support a few species which are not found with us.

The great majority of our wild plants naturally belong to the British (widely spread throughout Great Britain) and English (widely spread throughout England and Wales) types of distribution, but there is a sprinkling of species representing other types. Thus of Germanic species (chiefly seen in East England) we have Myosurus minimus, Hippuris vulgaris, Galium erectum and G. tricorne, Lactuca virosa, Campanula glomerata, Monotropa hypopitys, Limosella aquatica, Orchis pyramidalis and O. ustulata*, Allium oleraceum, Bromus erectus, Brachypodium pinnatum, Hordeum europaeum, etc. Of Scottish type are, among others,
Viola lutea*, Vicia sylvatica, Parnassia palustris, Antennaria dioica*, Crepis paludosa, Campanula latifolia, Pyrola minor*, Pinguicula vulgaris, Salix pentandra, Empetrum nigrum, Melica nutans*. Among species of Intermediate type (chiefly seen in Mid-Britain) we have Poterium officinale, Gagea lutea, Crocus nudiflorus and Scheuchzeria palustris*. Plants of the Atlantic type (chiefly seen in West England) are, as might be expected, few in number, and indeed not a single species is known to occur now, at any rate as a native; the recorded species are Coronopus didymus, Erodium moschatum and E. maritimum, Sedum anglicum and Veronica virgatum. Vaccinium vitis-idaea* is our only Highland species, and Selinium carvifolia the only representative of the Local type (restricted to single or few counties).

Botanical Districts

Nottinghamshire lies wholly within the drainage area of the Trent, so that the usual division of a county into river basins for botanical purposes is not possible in our case. The districts adopted (first published in the article on Botany in the Victoria History of Nottinghamshire) are therefore based on the geological structure of the county, and this division is a really natural one, for with the exception of the alluvial tracts bordering the Trent and its tributary streams little drift occurs to obscure the older deposits, and consequently the surface soil is principally formed by the disintegration and decay in situ of the underlying rocks. The wide differences in the physical and chemical composition of the resulting soils have of course a marked influence on the character of the flora of each formation.

Leaving out of consideration the superficial (drift and alluvial) deposits, the formations represented in Nottinghamshire are the Coal Measures, Permian, Trias (Bunter and Keuper), Rhaetic, and Lower Lias. These form bands running partially or completely through the county in a direction approximately north and south.

The outcrop of the Coal Measures forms a band sixteen miles long between Stapleford in the south and Teversal in the north, and varying in width from two to about four miles. To the east it is succeeded by the Permian or Magnesian Limestone which forms a narrow band running from Nottingham to the county boundary on the north, a distance of about thirty-two miles. At its maximum development it is about four miles in width, but for the most part is considerably narrower. The sandstones and conglomerates of the Bunter which follow occupy a much larger tract of land—nearly forty miles long by seven or eight in width over the greater part of its extent, except in the immediate neighbourhood of Nottingham, where it is much narrower.

Quite half the area of the county is occupied by deposits of Keuper age, but as the valley of the Trent lies almost wholly in this formation it is a good deal covered by alluvial deposits. The Rhaetic shales form a band of insignificant extent along the eastern margin of the Keuper.

*Species marked with an asterisk have not been seen in the county for many years and are probably extinct.
Finally, on the eastern and south-eastern border of the county for the southern two-thirds of its length the Keuper is succeeded by the lower beds of the Lias, which attain their maximum development south of Cotgrave and Cropwell Bishop. Two rather extensive outliers occur to the west of the main mass of the Lias in the extreme south of the county.

The botanical districts adopted, four in number, are as follows:

**District 1**

This comprises the area formed by the outcrops of the Coal Measures and Permian rocks on the western side of the county. It might seem at first sight that two such apparently dissimilar formations should constitute separate districts, but the area occupied by the Coal Measures is so small and its noteworthy plants so few in number that to make of it a separate district would be to ascribe to this formation an importance altogether out of proportion to its merits. Indeed the Coal Measures can scarcely claim to possess a distinctive flora at all: not a single species appears to be confined to their outcrop, and the few conspicuous plants that do occur are equally common elsewhere. On the other hand, the Magnesium Limestone possesses a large number of characteristic species, some of which are peculiar to it. Among these the following may be mentioned, the species hitherto found only on this formation being indicated by an asterisk.

- **Ranunculus lenormandi** Schultz.
- **Helleborus viridis** L.
- **Aquilegia vulgaris** L.
- **Arabis hirsuta** Scop.
- **Reseda lutea** L.
- **Helianthemum chamaecistus** Mill.
- **Silene cucubalus** Wib.
- **Hypericum montanum** L.
- **Geranium sanguineum** L.
- **Trifolium medium** L.
- **Anthyllis vulneraria** L.
- **Geum rivale** L.
- **Parnassia palustris** L.
- **Ribes alpinum** L.
- **Hippuris vulgaris** L.
- **Bupleurum rotundifolium** L.
- **Selinum carvifolia** L.
- **Galium mollugo** L.
- **Erigeron acre** L.
- **Inula squarrosa** Bernh.
- **Centaurea scabiosa** L.
- **Campanula trachelium** L.
- **latifolia** L.
- **Anagallis tenella** L.
- **Blackstonia perfoliata** Huds.
- **Gentiana amarella** L.

* **Helleborus viridis** L.
* **Myosotis arvensis** Hill; var. **silvestris** Schlech.
* **Lithospermum arvense** L.
* **Verbascum thapsus** L.
* **Lathraea squamaria** L.
* **Origanum vulgare** L.
* **Calamintha acinos** Clair.
* **Cephalanthera grandiflora** Gray
* **Orchis ustulata** L.
* **Ophrys apifera** Huds.

* **Muscifera** Huds.
* **Gymnadenia conopsea** Br.
* **Potamogeton coloratus** Horn.
* **Eriophorum latifolium** Hoppe.
* **Carex digitata** L.
* **pendula** Huds.
* **fulva** Host.
* **Melica nutans** L.
* **uniflora** Retz.
* **Hordeum europaeum** All.
* **Taxus baccata** L.
District II

This consists of the Bunter or lower division of the Trias, and includes the fine-grained red or variegated sands of the Lower Red and Mottled Sandstone, and the yellow or brownish sands and conglomerates of the Bunter Pebble-beds.

The district possesses a distinctive and characteristic flora, although, as will be seen from the list given below, a large proportion of the species occur elsewhere. This is due to the fact that most sand-loving plants find an equally suitable habitat in the sandy patches which occasionally occur in the Keuper Marl, in the tracts of sandy alluvium bordering the Trent in District III, and in the drift sands which cover a part of District IV on the eastern edge of the county.

The existing remains of the once far more extensive Sherwood Forest lie entirely in this district, and consist chiefly of oak and birch timber with a dense undergrowth of bracken, and open spaces covered with gorse (Ulex), ling (Calluna), heath (Erica cinerea), bracken (Pteris), Deschampsia flexuosa, etc., and dotted with old thorn trees often infested with mistletoe (Viscum).

A few bits of boggy ground are still to be found along the courses of some of the streams, as at Oxton and Rainworth, and to these we owe the survival of some of our most interesting plants. Of late years, however, owing partly to a succession of dry seasons and partly to the sinking of deep wells for the water supply of the surrounding towns, these bogs have become nearly dry at times, with the result that such things as the sundew (Drosera), butterwort (Pinguicula), cranberry (Oxyccoccus), the ferns Lastrea thelypteris, L. oreopteris, L. cristata and L. uliginosa, and our three species of Lycopodium, are fast disappearing or have already gone.

Among the characteristic plants of the district are the following:

- Ranunculus lingua L.
- Corydalis claviculata DC.
- Arabis glabra Bernh.
- Teesdalia nudicaulis Br.
- Viola palustris L.
- " ericetorum Schrad.
- " tricolor E.B. and its forms.
- Polygala serpyllacea Weihe.
- Dianthus deltoides L.
- Silene anglica L.
- " nutans L.
- Cerastium semidecandrum L.
- " arvense L.
- Moenchia erecta Gaertn.
- Sagina ciliata Fr.
- Spargularia rubra Presl.
- Montia fontana L.
- Hypericum humifusum L.
- Erodium cicutarium L'Hér.
- Genista anglica L.
- Ulex minor Roth.
- Medicago denticulata Wild.
- Trifolium subterraneum L.
- " arvense L.
- " striatum L.
- Ornithopus perpusillus L.
- Vicia lathyroides L.
- Lathyrus palustris L.
- Potentilla argentea L.
- " palustris Scop.
- Chrysosplenium alternifolium L.
- Drosera rotundifolia L.
- Epilobium adnatum Griseb.
- Galium saxatile L.
- Antennaria dioica Gaertn.
- Gnaphalium sylvaticum L.
- Senecio sylvaticus L.
- Arnoseris pusilla Gaertn.
- Hieracium tridentatum Fr.
- Jasione montana L.
**Scientific Survey of Nottingham and District**

*Vaccinium vitis-idaea L.*

"myrtillo L.

Oxyccoccus quadripetala Gilib.

Calluna vulgaris Hull.

Erica tetralix L.

"cinerea L.

*Monotropa hypopitys L.*

Lycopsis arvensis L.

Myosotis collina Hoffm.

"versicolor Sm.

Echium vulgare L.

Verbascum nigrum L.

Digitalis purpurea L.

Melampyrum pratense L.

Teucrium scorodonia L.

Plantago coronopus L.

Scleranthus annuus L.

Rumex acetosella L.

*Empetrum nigrum L.

**District III**

The Keuper deposits which underlie this extensive district are separable into two divisions. The lower of these, known as the 'Waterstones', consists of alternations of dull red marl and light-coloured greenish-grey sandstone; where the latter predominates the resulting soil is sufficiently sandy to suit many of the plants characteristic of District II, and we therefore find along the outercrop of the Lower Keuper an assemblage of species transitional in character between the flora of the Bunter and that of the upper beds of the Keuper. The upper division or Keuper Marl is a stiff bright-red clay with an occasional thin band of hard whitish or yellowish sandstone. The heavy somewhat calcareous clay soil supports a flora very different from that of District II, but more nearly approximating to that of District I, with which it has a large number of species in common. Among the more prominent plants that occur with about equal frequency in Districts I and III, but are almost or entirely absent from Districts II and IV, are *Anemone nemorosa*, *Euonymus europaeus*, *Pimpinella major*, *Asperula odorata*, *Lactuca muralis*, *Campanula latifolia*, *Lysimachia nemorum*, *Erythraea centaurium*, *Veronica montana*, *Lamium galeobdolon*, *Mercurialis perennis*, *Allium ursinum*, *Paris quadrifolia*, *Carex pendula*, *C. sylvatica*, *Milium effusum* and *Melica uniflora*. Several rare or uncommon Nottinghamshire species are confined to District III; of such are *Ranunculus sardous* and *R. parviflorus*, *Vicia sylvatica*, *Lathyrus sylvestris*, *Dipsacus pilosus*, *Carduus tenuiflorus*, *Campanula patula*, *Menpha pulegium*, *Carex gracilis*, *C. pallescens*, etc.; while among commoner species which are most abundant in, but not absolutely confined to, the District are *Geranium pratense*, *Bidens tripartita*, *Tanacetum vulgare*, *Picris hieracioides*, *Epipactis latifolia*, *Platanthera chlorantha*, etc.

A number of plants which have their headquarters in the Trent valley, which lies almost wholly in this District, owe their presence rather to their fondness for a moist or watery situation than to the chemical or
the arvense, Districts be solitary this and series one full congenial given Among the District of Teesdalia, narrow the long the few this Sison Wood, Myosotis known Lythrum sylvestre, Sphagnum; Wigsley C. covered entirely quantity others West outliers Lower erucifolius, characteristic alluvium palustris, Lichens, of Algae nature and Limitations The The Limitations of space forbid a detailed review of the cellular cryptogams of Nottinghamshire, but a full account of the local Mosses, Liverworts, Lichens, Algae and Fungi occurring in the county, with notes on their distribution, will be found in Vol. I of the Victoria History of Nottinghamshire. A detailed list of the Myxomycetes of the county is given in the Transactions of the Nottingham Naturalists’ Society for 1910-11.

physical nature of the soil. Such are Thalictrum flavum, Nasturtium sylvestre and N. amphibium, Erysimum cheiranthoides, Stellaria aquatica, Lythrum salicaria, Apium graveolens, Oenanthe aquatica, Hottonia palustris, Symphytum officinale, Polygonum hydropiper, etc.

On the other hand, the dry gravelly banks and terraces of old Trent alluvium offer a congenial home for many of the sand-loving plants characteristic of District II.

A few species which are more or less common in District III are of equally frequent occurrence in District IV, but almost or entirely unknown in Districts I and II. Among these are Conium maculatum, Sison amomum, Peucedanum sativum, Dipsacus sylvestris, Senecio erucifolius, Picris echioides. Lactuca virosa, Hordeum nodosum, etc.

The Rhaetic deposits which are included in District III form a narrow band of such insignificant extent along the eastern edge of the Keuper as to be of no botanical importance, and may therefore be ignored.

**DISTRICT IV**

The Liassic beds of Nottinghamshire consist of a series of blue clays and shales with bands of limestone, belonging to the lower part of the Lower Lias, and forming a long strip overlying the Triassic rocks along the south-eastern border of the county. There are also two considerable outliers capping the hills south of the Trent between Thrumpton and West Leake. Sison, Peucedanum sativum, Senecio erucifolius and a few others are common plants in this district; Cnicus eriophorus occurs in quantity in one or two stations; and among other species almost or entirely confined to this formation are Lotus tenuis, Carum segetum, Caucais arvensis, Galium tricoine, Linaria spuria, Calamintha nepeta, Galeopsis angustifolia and Carex binervis.

In parts of District IV, as at Langford and Wigsley, the Liassic clay is covered by a mantle of gravelly drift supporting the usual assemblage of sand-loving plants, such as Teesdalia, Cerastium semidecandrum and C. arvense, Polygala serpyllacea, Galium sylvestre, Filaga minima, Gnaphalium sylvaticum, Senecio sylvaticus, Calluna, Erica cinerea, Myosotis versicolor, Salix repens, Nardus, etc. Langford Moor and Wigsley Wood were formerly wet swampy moorland, and although long drained and planted with oak and fir, still show traces of their ancient flora. Erica tetralix, Lysimachia vulgaris, Myrica gale, Molinia coerulea and Lastrea spinulosa still persist in fair quantity, as well as patches of Sphagnum; and a solitary plant of Osmunda, probably the last in the county, was seen about 40 years ago, but has since disappeared. Wigsley Wood, too, is the only Nottinghamshire station for Convallaria majalis which is abundant there.

**CELLULAR CRYPTOGRAMS**

Limitations of space forbid a detailed review of the cellular cryptogams of Nottinghamshire, but a full account of the local Mosses, Liverworts, Lichens, Algae and Fungi occurring in the county, with notes on their distribution, will be found in Vol. I of the Victoria History of Nottinghamshire.
iv. THE ZOOLOGY OF NOTTINGHAMSHIRE

BY

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Mammalia

Most of the larger indigenous mammals of Nottinghamshire disappeared long ago, but there can be no doubt that at one time Sherwood Forest, which once covered a considerable part of the county, afforded shelter to most of the British species. The red deer was abundant, the wolf, pine-marten, pole cat, badger and otter were all probably common, and some have survived even to the present day.

Of the Chiroptera or Bats, the Long-eared Bat (Plecotus auritus), Noctule (Pipistrellus noctula), and Pipistrelle (P. pipistrellus) are all common, but only single specimens of the Lesser Horse-shoe (Rhinolophus hipposideros) and Natterer’s bat (Myotis nattereri) have occurred. The Greater Horse-shoe bat (R. ferrum-equinum) has been reported from Sherwood Forest, but requires confirmation before it can be accepted as a Nottinghamshire species.

The Insectivora include the Hedgehog (Erinaceus europaeus), Mole (Talpa europaea) and Shrew (Sorex araneus), which are all of common occurrence; while the Water-shrew (Neomys fodiens) is widely distributed though not often seen, and the Pigmy shrew (Sorex minutus) is recorded from Rainworth near Mansfield.

Among the Carnivora the Badger (Meles meles) and Otter (Lutra lutra) are by no means rare; the Fox is, of course, common owing to its preservation for purposes of sport; the Pole-cat (Putorius putorius) occurred frequently during the last quarter of the nineteenth century, but is probably now extinct, as is also the Pine-marten (Mustela martes) which occurred at least up to about 1872; the Stoat (Putorius ermineus) and the Weasel (Putorius nivalis) are still very common throughout the county; the Wolf (Canis lupus) is shown by documentary evidence to have been common in the Forest as late as the fifteenth century at least, but no remains of the Wild-cat (Felis catus) are known of later date than the recent deposits in the Creswell caves.

Rodentia. The Squirrel (Sciurus leucourus) is common in woods and parks throughout the county; the Dormouse (Muscardinus avellanarius) and the Harvest-mouse (Mus minutus) both occur, but are now very rare; the Wood-mouse, or Long-tailed Field-mouse (Mus sylvaticus) is common in the Nottingham district and doubtless elsewhere; the House-mouse (Mus musculus) and Brown-rat (Mus decumanus) are here, as elsewhere, abundant pests; the Field-voile (Microtus agrestis) and Bank-voile (Evotomys glareolus) occur and are probably common, but have not been much looked for; the Water-voile (Microtus amphibius) is common in all
suitable localities; the Hare (Lepus europaeus) is very common, and the Rabbit (Lepus cuniculus) occurs in great abundance.

**UNGULATA.** The Red-deer was formerly abundant in a wild state in Sherwood Forest. A survey taken in 1635 gives the number of deer in the Forest as 1,367, and as late as the reign of Queen Anne a yearly grant of £1,000 was made for the maintenance of a hunting establishment there. At this time they were so numerous as to cause great loss to the surrounding landowners by feeding upon their crops, and many complaints were made against 'the intolerable burden of the Queen's deer'. The subsequent disafforestation and enclosure of the district resulted in the reduction of the herds and their confinement in a semi-domesticated state within the limits of the parks formed out of the ancient forest.

[Fallow-deer have been introduced into many of the principal parks. The Roe-deer formerly occurred, as its bones have been found in superficial deposits at Wheatley, near Retford, and in the Creswell caves. Remains of the Wild-boar (Sus scrofa) and wild Cattle (Bos taurus) occur in the recent deposits in the Creswell caves, and herds of 'Wild White Cattle' formerly existed in Wollaton and Annesley Parks.]

**CETACEA.** The Porpoise (Phocoena phocoena) occurs very frequently in the tidal portion of the Trent, and occasionally ascends the river as far as Newark.

**AVES**

For an inland county, Nottinghamshire possesses a fairly rich avifauna, no fewer than 259 fully-authenticated species having occurred within its borders. A detailed account of these is given by the late J. Whitaker in his *Birds of Nottinghamshire* (Nottingham, 1907). The substance of the notes which follow is taken from this work or from the same author's article in the *Victoria History* (1906).

The extreme northern part of the county lies very low, often only a few feet above sea-level, and is drained by sluggish streams and many dykes; this region is frequented by the Redshank and Snipe which find it a congenial breeding ground. Further south is the forest land with a considerable area of ancient woodland, mainly oak and birch. In the old hollow oaks hundreds of Jackdaws nest. The open forest includes a large stretch of ling and heath with occasional clusters of fir and other trees: here a few black-game still linger. On several of the great estates comprised in this region—such as Welbeck, Clumber, Thoresby and Rufford—are large lakes which attract great numbers of water-fowl of many species. On the Rainworth ponds numbers of tufted Duck have nested for over a century. On all these estates the birds are carefully protected, and the same is true of the Sherwood Lodge, Bestwood and Annesley Parks. They accordingly form safe sanctuaries for numerous species of birds. Duck-decoys exist at Annesley Park and Park Hall.

The Trent runs through the greater part of the county from south-west to north-east and forms a natural highway from the sea for many species of sea-birds and water-fowl.

In the southern part of the county there are large areas of grass-land
with occasional woods and plantations: this region is rich in warblers and finches.

Mr. Whitaker claims that no place in Nottinghamshire has a larger or more varied avifauna than Rainworth, 155 species having been seen by him within a radius of one mile around Rainworth Lodge.

Extensive collections of Nottinghamshire birds exist in the Museums at Nottingham and Mansfield, and the former Museum possesses the magnificent collection of the eggs of Nottinghamshire birds formed by Mr. F. B. Whitlock and including full clutches of practically every species breeding in the county.

**Reptilia and Batrachia**

Only the commonest of the reptiles and batrachians occur in Nottinghamshire, and even of these the slow-worm and viper are now rare. Sterland’s assertion (in White’s *Worksop, the Dukery and Sherwood Forest*) that the sand-lizard (*Lacerta agilis*) ‘may be seen occasionally in Sherwood Forest’ is doubtless an error.

Only four species of reptilia and four batrachians are found in the county. Of the former, the Common Lizard (*Lacerta vivipara*) was formerly common in Nottingham Park, on Nottingham Forest, and on other sandy gorse-covered commons about the city, but the absorption of most of its former haunts within the ever-increasing area covered by bricks and mortar has almost exterminated the lizard in this neighbourhood. It was very common on Bulwell Forest about the beginning of the present century, but the laying out of the Forest as a golf-course has greatly reduced its numbers. It has been seen comparatively recently on the Barrow Hills at Everton in north Nottinghamshire, and near Worksop. The Slow-worm or Blind-worm (*Anguis fragilis*) was at one time frequent in Sherwood Forest according to Sterland, and has been seen in several widely-separated localities in the county in recent years. The Common or Ringed Snake (*Tropidonotus natrix*) is fairly common and generally distributed. The Viper or Adder (*Vipera berus*), on the other hand, is now very rare, but has been seen in Sherwood Forest, at Rainworth. Worksop, Oxton, Newstead Park, etc.

Of batrachians, the Frog (*Rana temporaria*) and Toad (*Bufo vulgaris*) are, of course, abundant, and both the Crested and Common Newt (*Molge cristata* and *Molge vulgaris*) are common and generally distributed in the county, particularly the latter; the Palmated Newt (*Molge palmata*) has so far not been observed in Nottinghamshire.

**Pisces**

Thirty species of fishes are certainly known to occur in the county, and it is noteworthy that twenty-two of these are enumerated as inhabiting the Nottinghamshire Trent over 300 years ago, in Michael Drayton’s poem the Poly-Olbion (1622). Among the more interesting species are the Burbot (*Lota vulgaris*), rare in the Trent; the Flounder (*Pleuronectes flesus*), common in the Trent below Newark and occasionally making its way up the river as far as Colwick Weir, close to Nottingham; Spined
Loach (*Cobitis taenia*), and Shad (*Cloepea alosa*), both rare in the Trent; Sturgeon (*Acipenser sturio*), captured in the Trent at Clifton and at Cromwell and Muskham; and the Lamprey (*Petromyzon marinus*), caught occasionally in the Trent.

**Invertebrata**

The invertebrate animals of Nottinghamshire had been so little worked that when the British Association last met in Nottingham in 1893 the only groups of which any account could be given in the *Handbook* were the Lepidoptera, the Mollusca, and, curiously enough, the terrestrial Annelida or Earthworms. During the next twelve years this neglect was so far repaired that in the *Victoria History of Nottinghamshire* (1906) fairly extensive lists were given of most of the invertebrate groups. Then followed ten years of great activity in the investigation of our local invertebrates, and in 1916 the results of this work were published in *The Invertebrate Fauna of Nottinghamshire* by J. W. Carr, the first separate work of its kind to be published for any British county. This book of over 600 pages gives an account of the structure and mode of life of the animals belonging to every class and order of the invertebrata, together with details of the distribution of every species found in the county.

A complete analysis of the 5,330 species recorded would be tedious reading, but a few examples may be cited.

The number of species of *Lepidoptera* recorded for the county previous to 1893 was about 670, and the great majority of these were collected by the late R. E. Brameld, of Retford, in the neighbourhood of that town and in Sherwood Forest. In 1916 the number had risen to 933. This increase, though fairly large, might easily have been much greater, but the smaller moths—the so-called Micro-Lepidoptera—have been much neglected by our local lepidopterists.

Of the *Coleoptera* no list could be given in the 1893 British Association Handbook, but, thanks to the splendid work accomplished by the Rev. A. Thornley, the late W. E. Ryles, and others, the list in the *Victoria History* actually comprised 1,280 species; and this number had increased to 1,409 in 1916.

The *Trichoptera* or Caddis-flies found in Nottinghamshire numbered 45 in 1906 and 65 in 1916. The *Hemiptera* (Plant-bugs, etc.) were 162 and 410 respectively, a very notable increase. Other large advances were made in the *Hymenoptera* (385 in 1906, 892 in 1916) and the *Diptera* (347 and 921).

Of invertebrates other than insects the best-worked group is the *Arachnida* (spiders, harvestmen, false-scorpions and mites). Not a single species of spider or other member of the class had been recorded before 1904, when a preliminary list was published in the *Trans. Nottingham Naturalists' Society*. In the *Victoria History* 169 species were enumerated, and in the *Invertebrate Fauna* 247.

A group of animals that would seem to offer few attractions to the average field-naturalist is the *Annelida*, which includes the earthworms. The Rev. H. Friend is one of the very few students of this group in
England, and in the years 1910-1913 he contributed to the Naturalists’ Society Transactions three important papers on the species occurring in Nottinghamshire, amounting to 87 in number—the largest number recorded for any British county.

The Mollusca enumerated in the Invertebrate Fauna comprise 116 out of the 145 indigenous non-marine species recorded for the British Isles, besides three others which have been found in a semi-fossil state in recent deposits, but have not been seen alive in the county. These figures are satisfactory when account is taken of the fact that the soils of Nottinghamshire are not very suitable for the terrestrial species owing to the predominance of sand and clay and the comparative absence of calcareous formations. Molluscs have always been favourite objects with Nottingham naturalists, and were indeed the only invertebrates dealt with in the Handbook to Nottingham issued in 1866 in connection with the first visit of the British Association to Nottingham. This article was by E. J. Lowe, F.R.S., who had previously (in 1853) published an illustrated work on the Conchology of Nottingham. Other papers on the Nottinghamshire mollusca were published from time to time by C. T. Musson, W. A. Gain and B. S. Dodd, and an article by the last-named was included in The British Association Handbook for 1893. Finally, in 1906, B. S. Dodd and B. B. Woodward summarised all our existing knowledge of the Nottinghamshire mollusca in the Victoria History of Nottinghamshire.

Other invertebrates found in the county and recorded in the Invertebrate Fauna of Nottinghamshire are a sponge, four species of Hydrozoa, many Rotifera, five Polyzoa, eleven Crustacea belonging to the sub-class Malacostraca, and many Entomostraca, twenty-four species of Myriapoda, etc.

Since the publication of the above work a large amount of new material has been accumulated, and the results of this intensive collecting were presented in a bulky Supplement issued in January 1935. No fewer than 1,255 species were added to our invertebrate fauna in this Supplement, bringing the total for the county up to 6,585. Of the 1,255 additional species, 1,228 are insects, the rest comprising Nematodes, Hirudinea, Crustacea and Acarina. The Diptera and Hymenoptera account for the majority of the insects, the additional species of the former numbering 691 and of the latter 399; among these are several species new to Britain and many others that are little known or of extremely rare occurrence. The other species new to Nottinghamshire include: Hemiptera 58, Coleoptera 40, Trichoptera 14, Lepidoptera 12, and a few representatives of the smaller orders.

Between January 1935 and August 1936, 64 additional species of insects have been identified, and these are included in the totals given below. A very large amount of unidentified material still awaits working out, and when this is done many more species will be added to most of the insect groups.
### Synopsis of Nottinghamshire Invertebrata.

<table>
<thead>
<tr>
<th>Group</th>
<th>Species</th>
<th>Count</th>
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<td>Hydrozoa</td>
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</tr>
<tr>
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</tr>
</tbody>
</table>

**Total:** 6650

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### V. The Agriculture of Nottinghamshire

**By**

H. G. ROBINSON, M.Sc.,

Principal of the Midland Agricultural College.

The Agriculture of Counties in the past has been determined very largely by a great many local features which together have exercised such an influence as to enable distinctions to be drawn between one district and another. In this sense it has been possible to forecast the peculiar features if one knew something of soils and climate, or if it was known that the surrounding district was associated with industrial activities or otherwise. These distinctions are not quite so marked as they were at one time. The convenience of transport by rivers or railways has for example been affected by the vast development of road transport, and it is probably not so widely recognised as it should be that road transport is altering the face of counties even so far as the practice of agriculture is concerned. The knowledge of other systems of farming that tends to become more widely known as a result of education and reading is also promoting a greater measure of uniformity in good farming practice, especially when intelligent men are anxious to promote their own well-being by the practice of economic systems of agriculture. This does not mean that no local problems remain. There never can be any complete solution of farming problems because of the diversity of soils and climates, and the varying qualities in livestock and crops as well as of the farming community itself. There is no certain road to success because each case has to be considered on its merits and there is a wide field for the display of originality, common sense and energy in tackling the variety of work with which the agriculturist has to contend.
Nottinghamshire is one of the counties that has been influenced by the progress of civilisation and the development of an industrial community particularly along its western borders. While there yet remains a great area of the county essentially unaltered, one cannot overlook the influence exerted by the great coal field in the west of the county, and the industrial development around the city of Nottingham itself in the southern portion of the county. Developments of this kind mean a great deal to the prosperity of the agricultural community, for not only are good markets provided for certain agricultural commodities, but it frequently happens that the character of the agricultural systems practised undergoes fundamental changes to meet new market requirements. This fact is mentioned because certain districts used to be regarded as favourable for the practice of particular types of farming. Under the present developments that are taking place, however, close proximity to a good market does not carry as much importance as it did, largely because of the added ease with which markets can be reached from a distance as a result of motor transport. This fact may result in the long run in re-establishing the principle that the agriculture of a district should revert to the farming policy for which it is best fitted by reason of soil and climatic conditions. It does raise another interesting point, however, in that such a course might lead to a new appreciation of values so far as rents are concerned in their application to agricultural land. This is already being felt with regard to the price standardisation that is applicable to milk under the operations of the Milk Marketing Scheme.

Situation and Climate

Nottinghamshire is a long, narrow county, its greatest width being about 27 miles and its length stretches in a north easterly direction for about 51 miles. Its shape and its contact with the neighbouring counties has to some extent influenced the particular agricultural practices so that one can never speak with confidence of a peculiarly local agriculture.

The dominant geographical feature is the association of the county with the valley of the river Trent, which enters at the south-west, making for the eastern boundary and leaving at the north-east corner. The Trent Valley covers an extensive area, and gives rise to a considerable acreage of low-lying land that in many cases is only a few feet above water level and liable to flooding after heavy rains. The greater part of the county is low lying, as much as two-fifths of the total area being under 100 feet above sea level, and only one-fifty-sixth of the area being over 600 feet above sea level. This higher lying ground is concentrated to the west of the county adjacent to the Derbyshire borders, in the district around Mansfield.

So far as rainfall is concerned the county falls within the dry belt, for right throughout the Trent Valley or approximately the eastern half of the county it is 25 inches. There is a rise however up to 30 inches in the district around Sutton-in-Ashfield, while the greater part of the western half averages between 25 and 27½ inches annually—the increases following the contours. Figures collected at the Midland Agricultural College in the south-westerly corner of the county for the past ten years indicate
an average rainfall of just under 24 inches, the months from December to May inclusive being the driest, and March having the lowest figures of any. The sunshine figures for the same period indicate an average of about 1,300 hours of bright sunshine.

The relatively low rainfall figures which are somewhat surprising to the stranger to the county have a considerable bearing on the prosperity or otherwise of a certain farming area in the county. This is the district that is popularly known as the Forest of Sherwood where, on the Bunter Sandstone outcrop, dry periods in the spring of the year are often sufficient to ruin farming prospects.

The Chief Soils

The soils in the county are almost entirely typical of the underlying geological strata from which they have been derived. The principal soil types are:

1. Bunter

The Bunter outcrop is one of the features of the county in that it occupies an area of approximately 240 square miles, or nearly one-third of the total area. It extends in a straight belt from Nottingham northwards to Bawtry and is some six or seven miles wide and includes the districts between Worksop and Retford, Mansfield and Southwell. Both high and low-lying ground is included in the area and it is sub-divided into a fine-grained, loamy sand on the one hand and pebble beds on the other. Actually the pebble beds constitute the major part of the area. It can be readily understood that this type of soil constitutes a major agricultural problem in the county, on which the effect of the agricultural depression has been keenly felt in recent years. The pebble bed areas give rise to a very light porous soil, incapable of holding moisture in the natural state. Much of the area is given over to waste and common, as is typified by Sherwood Forest. The agricultural productivity of these soils is determined by a variety of factors. Their situation and the character of the subsoil is important, but the primary requirement is the practice of a system of agriculture that will add to the organic matter in the soil so as to increase the water-retaining capacities. In the days when farming was more profitable, high farming was considered the only sound practice on these soils, involving considerable dependence upon livestock in the form of fattening cattle and sheep for the production of farmyard manure, together with the liberal use of organic fertilisers and purchased foodstuffs. The rotation in the old days was the standard four course, which was modified to suit the local conditions of need for more 'body' in the soil by extending to a five course or longer, through leaving the seeds down for two or more years instead of one. In pre-depression days some support was given to the use of seeds mixtures containing deep-rooting plants similar to those utilised in the typical Clifton Park mixtures. Apart from the porous character of these soils, the inherent fertility is low, since they are markedly deficient in potash, lime and nitrogen, though the phosphoric acid reserve is usually satisfactory. The term 'hungry' applied to this land is fully descriptive of its reputation, but modern manuring as we understand it to-day is futile on this land
unless it is associated with a live stock policy for the production of 'muck' or unless the season is favourable as regards a frequent supply of rainfall. It would appear that the depression has caused most of these farmers to hope for the best support that the weather can give. A study of rainfall records reveals that even this is a very slender aid, for within the last sixty years nearly two years out of three lacked a sufficiency of rainfall during the spring and early summer to ensure safe cropping results.

A recent survey by the Midland Agricultural College of sand land farming in the Sherwood Forest area, covering farms that had a combined area of just over 12,000 acres, indicated that about 70 per cent was under the plough, while over one-third of the permanent grass was regarded as rough-grazings. There has been a marked change in the character of the cropping in recent years, in that cropping for convenience has tended to displace the conventional rotations. However, 45 per cent of the arable area was found to be devoted to cereals, nearly half of which was oats. Formerly this was a typical barley-growing district, but with lime deficiencies becoming more marked, oats and wheat are generally found to be more profitable. The light character of the soil and its workability at all seasons gives rise to very low cultivation costs, though it should be noted that weeds spread very rapidly if neglect occurs. A small acreage of rye is still grown—chiefly because it suits the land, and gives rise to good sheep food and also straw for thatching. Root crops occupied about a quarter of the arable area, and of the feeding crops, swedes and common turnips were the most popular, with a smaller acreage of kale and mangolds. It will be recognised that this in the main meets sheep folding needs. Potatoes and sugar beet are grown under suitable conditions, while peas are also an occasional crop. Prior to the introduction of the beet crop it was the usual custom to grow roots on the ridge, for this enabled the dung to be well-covered and this incidentally was always applied in the well-rotted condition.

2. THE KEPUPER MARL

As a sharp contrast to the poverty-stricken Bunter sands, there is an equally characteristic stretch of Keuper Marl that runs to the east of the Bunter and almost parallel with it from Normanton-on-Soar in the south and to Walkeringham in the north. The Valley of the Trent divides the Keuper Marl, for on the right of the valley it extends from the river Soar, through Newark to North Clifton. On the left side of the valley it starts at Sandiacre and proceeds through Nottingham, Southwell, Tuxford, to the west of Retford, meeting the junction of the rivers Trent and Idle. The Keuper Marl soils are chiefly very heavy, of a rich red colour, and although they are clays in character are not so in actual fact. They are inclined to be variable however, in respect of 'heaviness', since free working patches occur, though the typical Keuper Marl is three-horse land. The Keuper soils in the south of the county are generally regarded as being more fertile than those in the north. In general they are well-equipped with potash reserves, as well as nitrogen and organic matter. They are markedly deficient in phosphates however, while lime is also found to have a marked influence not
only in increasing fertility but also in producing better working soils when these are under the plough. Much of this land has been laid down to grass in recent years, though it is typical of good 'wheat and bean' land. The Keuper soils are specially good for fruit trees, which probably explains the development of fruit-growing in the Tuxford, Wheatley, Southwell and Woodborough districts. It is an interesting feature of the water supplies in the Keuper Marl areas that it is often impregnated with gypsum and iron.

3. Alluvial Soils

These soils total about 170 square miles or 13 per cent of the area of the county, and the valley of the Trent is responsible for the greater part of this. Agriculturally, these soils are fertile, identified with arable and mixed farming, while on the right bank of the river there is much good grazing land. It is a feature of the Trent Valley that the 'alluvium' rests on a bed of coarse gravel of from 15 to 25 feet deep. Towards Collingham a very sandy soil is experienced, which is associated with the growing of good quality carrots.

In the north of the county there is an area of land known as the 'Carr' where the soil consists of decayed vegetable matter—the product of old marsh land before it was drained by the Romans in the first instance and later by Dutch engineers. Warping has also been practised, and the general result is an arable soil that proves excellent for potatoes, sugar beet, wheat and various market garden crops, including celery.

Agricultural Holdings and Land Tenure

The position in Nottinghamshire is very similar to that in other counties, in that by far the greater majority of farms can be classified as small holdings. The smaller farms are usually found on the better classes of soil. This is a natural tendency since the ease with which land yields a return has a considerable bearing on the competition for land. It has to be recognised also that even on the poorer soils, such as those on the Bunter, there are many agricultural holdings established by virtue of mining populations close at hand. Coal has been a great asset to the landowners in these parts, since the income from this has made possible the development of agricultural estates, which but for coal, might otherwise have been heathland and deer forest to-day. The total number of agricultural holdings is about 6,000 of which 20 per cent are between 1 to 5 acres, 27 per cent between 5 to 20 acres, 17 per cent between 20 to 50 acres, 14 per cent between 50 to 100 acres, 8 per cent between 100 to 150, 11 per cent between 150 to 300, and with only 3 per cent over this acreage. There are approximately 2,000 fewer separate holdings than in 1885.

The agricultural features of these holdings is that over 60 per cent of them are devoted to the practice of mixed farming, just over 20 per cent are arable farms, and just under 20 per cent are mainly devoted to grassland. This again is quite in keeping with the prevailing tendency throughout the country to safeguard farming capital by mixed systems.

There is one outstanding village in the county where the ancient open field system of farming still survives. This is Laxton and here the
three open fields system still remains and functions in much the same way as it did right back to Anglo-Saxon times. The rotation under this system is (1) fallow, (2) wheat or barley, (3) beans or peas.

The customary date of entry to farms in the county is Lady Day.

Cropping Features

The total area of agricultural land is 422,697 acres. There has been a gradual decline in the agricultural area since records were first available. This is general throughout the country and in this county results from the extension of coal mining interests and building developments.

There has been a gradual decline in the acreage of arable land though this is not so marked a feature as in some counties. The proportion of arable to grass is more or less equal, with a tendency for the grass to increase. It may be remarked in this connection that the laying down to grass is not readily accomplished in the typical arable districts in the county, while with two beet factories in the county, considerable attention has been paid to this crop.

The four course rotation, with modifications, is the custom of the county. The modifications have become more marked in recent years, and particularly since the effects of the depression have driven farmers to grow crops that promised to leave the best financial results. Wheat and oats are the most extensively grown of the cereals. Wheat has proved a standby even on the lighter soil types that at one time were considered unsuitable for this crop. This is largely the result of the employment of varieties like Little Joss and Red Standard that are suitable for light soils. The decline in the cultivation of barley is probably one of the most marked of the cropping features, and there is actually a greater acreage under beans and peas than under barley.

Of the root crops, turnips, and swedes are still the most popular, but on the suitable soils, sugar beet has played an increasingly important part in the general farming policy, and, as in most arable districts, this crop has proved to be of great value, the area under the crop totalling just over a quarter of the ground devoted to root crops.

Live Stock

The outstanding features so far as the livestock interests are concerned are that in the last fifty years there has been a considerable decline in the sheep population and a gradual though by no means marked increase in the number of cattle. It is interesting to note that the sheep stocks were being reduced in the years preceding the war, but they reached their lowest figures from 1920-23. Livestock play a prominent part in the maintenance of soil fertility in this county, especially on the Bunter soils. Many have changed over to dairying, and some very notable herds are to be found in the district. Actually Nottinghamshire possesses no distinctive breeds of its own. The majority of the sheep that are kept are cross-breds, while Shorthorns are the dominant breed of cattle, though some very good herds of Friesians, Jerseys and Aberdeen Angus are distributed throughout the county. Pigs have never been regarded with great seriousness until recent years, and there is little doubt that kept in
greater numbers these could prove one of the solutions to the problem of making enough muck to apply to some of the hungry soils in the county. This has been demonstrated by some with great success. Horses too have never been particularly numerous, but they are now fewer than at any previous stage in the last fifty years. This is again explained by the increased use that is being made of tractors.

The interest taken in livestock improvement in the past has been influenced by the landowning community, an outstanding example among these being that of the Welbeck Estate.

**Agricultural Education**

The part which education has played in the farming economy of the county is considerable. Nottingham University College through its Agricultural Department was responsible for the organisation of the early work. The foundation of a Dairy Institute at Kingston-on-Soar in 1895 by the County Councils of Nottinghamshire, Derbyshire, Leicestershire and Lindsey, was one of the earliest efforts in providing technical education in this important branch of Agriculture. The experiences at Kingston suggested that it was not ideal for agricultural teaching to be given in the heart of a city away from close contact with the actual problems. In 1902 the Agricultural Department was transferred from University College to Kingston-on-Soar. The subsequent development of the Midland Agricultural College was made possible by the continued co-operation of the County Councils whose first interests were concerned with the provision of technical instruction in Dairying. By 1913, a new site was found at Sutton Bonington to establish a modern College that would be equal to the growing demands for education in Agriculture. Since 1919 Sutton Bonington has been the headquarters of the Midland Agricultural College. The College is the advisory centre for the counties of Derbyshire, Kesteven, Leicestershire, Lindsey, Nottinghamshire and Rutland, the County Councils being active partners in the government and support of the College.

The College is not responsible for any direct work in the associated Counties, except through the advisory service, which works in co-operation with the Agricultural Staffs in each county. The local agricultural education staffs have developed the system of giving organised day class instruction in agriculture during the winter months, the award of scholarships to the Midland College being based largely on results in such classes.
vi. **THE UNDERGROUND WATER OF NOTTINGHAMSHIRE**

**BY**

R. C. S. WALTERS, B.Sc., M.Inst. C.E., F.G.S.

The accompanying map shows broadly the travel of water underground in the Bunter Sandstones and Pebble Beds of Nottinghamshire. The contours are related to feet above sea level or ordnance datum and are based on the many records published in the Water Supply Memoir of Nottinghamshire of H.M. Geological Survey, including the top portion in the neighbourhood of Bawtry and East Retford worked out by Dr. Bernard Smith.

The surface configuration does not appear to affect the general direction of flow in minute detail, but from the broad standpoint the underground water level does follow the surface configuration, the slope of which generally varies from north-east to south-east; north-east towards Retford and east between Tuxford and Southwell under the Keuper Marl where the water tends to become saline, and south-east between Southwell and Nottingham. The highest underground levels appear to be in the neighbourhood of Mansfield where the contours would merge into the underlying Magnesium Limestone. Rivers such as the Poulter and Meden tend to flow in the same direction as the contours.
IV.
NOTTINGHAM'S RIVER—THE TRENT

i. THE RIVER TRENT CATCHMENT BOARD AND ITS WORK

BY
WALTER H. HAILE, M.Inst. C.E.,
ENGINEER TO THE RIVER TRENT CATCHMENT BOARD.

GENERAL AND PHYSICAL FEATURES OF THE TRENT

The Catchment Area of the River Trent covers a large portion of the ancient kingdom of Mercia and is 2,578,539 acres (4,029 square miles) in extent. It comprises parts of the counties of Derby, Leicester, Lincoln-Kesteven, Lincoln-Lindsey, Nottingham, Rutland, Shropshire, Stafford, Warwick, Worcester and Yorkshire West Riding, and includes important County Boroughs such as Birmingham, Derby, Leicester, Nottingham and Stoke-on-Trent. The watershed line is difficult to define without reference to a map, but may roughly be described as having its northern limits at the Humber and in the Peak Districts, its western limits near the western Staffordshire County Boundary, its southern limits extending from south of Birmingham to south of Leicester, and its eastern limits extending from the hill range which divides the valleys of the Trent and the Ancholme to Rutland. The River Trent rises in the northern environments of Stoke-on-Trent and follows a south-easterly course until it reaches its confluence with the River Tame near Alrewas, when it changes to a north-easterly direction, and then from Newark to its outfall at Trent Falls in the Humber it flows practically due north. All the main tributaries, such as the Tame, Soar, Dove and Derwent, join the parent river above Nottingham, with the exception of the Idle which discharges at West Stockwith below Gainsborough.

With the exception of the River Derwent which flows through a gorge of millstone grit in its length above Ambergate, all the main rivers flow through alluvial beds composed of gravel until the River Trent reaches the vicinity of Torksey, where there is a fairly definite change to warp which overlies clay in places. For the most part, the geological formation of the land contiguous to the valleys is the Keuper marl, whilst the flat alluvial peat moors in the area of the Doncaster Drainage Districts are notable.

The River Trent is tidal for a length of 52 miles, from its outfall to a few miles north of Newark at Cromwell Lock. Navigation, assisted
by a series of locks, extends as far as Sawley, a distance of 92 miles from
the outfall, although a short length of the river, from Trent Bridge to
Beeston Lock, is unnavigable and boats have to pass from one reach to
the other via the Beeston Canal. Many weirs span the rivers in the upper
reaches and serve mills for industrial purposes.

**The Land Drainage Act of 1930**

The control of the main rivers from a land drainage point of view is
in the hands of the River Trent Catchment Board which was set up under
the Land Drainage Act of 1930 and commenced active duties in October
1931. The powers and duties of this and other Catchment Boards are
set out in the Act and need only be referred to very briefly in this Article.
The chief powers of the Board in respect of the ‘main river’ are set out
below under three heads, ‘main river’ meaning the lengths of waterways
of a total of 570 miles designated by the Ministry of Agriculture and
Fisheries to be under the direct jurisdiction of the Catchment Board.
(a) To maintain existing works (i.e. to cleanse, repair or otherwise main-
tain in a due state of efficiency any existing watercourse or drainage
works).
(b) To improve any existing works (i.e. to deepen, widen, straighten or
otherwise improve any existing watercourse or remove mill, dam,
weir or other obstructions to watercourses or raise, widen or other-
wise improve any existing drainage work).
(c) To construct new works (i.e. to make any new watercourse or drain-
age work or erect any machinery or do any other act required for
the drainage of the area comprised within the drainage district).

The Act interprets ‘drainage’ as including defence against water, irriga-
tion, warping and the supply of water. The Catchment Board’s activi-
ties, therefore, are by no means solely concerned with the voiding of
flood waters to the sea and alleviating flooding, but are also directed to
the conservancy of river water for all riparian interests, of which Agri-
culture and Industry are probably the most important.

**The Work of the River Trent Catchment Board**

Prior to the setting up of the Catchment Board, there was very little
data available except in respect of certain levels in the navigation reach,
but the May 1932 flood, which was of exceptional severity, fortuitously
offered a means of obtaining much useful information upon which
schemes for flood alleviation could be formulated. This flood resulted in
some 150,000 acres of land including many urban districts, such as West
Bridgford, Long Eaton, Tamworth and Nuneaton becoming submerged,
whilst the total area which can be said to have been affected by the flood
was approximately 374,000 acres.

It was early apparent that much pioneer work required to be carried
out before any comprehensive flood alleviation schemes could be con-
sidered and the first practical work of the Board comprised tree clearing,
removal of shoals and the reinstatement of flood banks of all main rivers
on an extensive scale. No less than 350 miles of rivers were cleared of
obstructive trees for instance; and the result of this pioneer work has
had an excellent effect on the lands by lowering the water table and hence preventing water-logging besides accelerating discharge.

Meanwhile, a complete hydraulic survey of the river systems was put in hand from which a comprehensive scheme is being prepared, parts of which are now in progress. The scheme, which is estimated to cost two and a quarter million pounds and to be carried out in fifteen years, comprises, *inter alia*, the following works:—

A Comprehensive Pumping Scheme for the low lying lands in the region of the Isle of Axholme, including the Hatfield Chase Area—historically famous for the works carried out by the great Anglo-Dutch engineer, Sir Cornelius Vermuyden in the reign of Charles I; tidal bank works of some magnitude in the lower reaches of the River Trent; the regrading and resectioning of all rivers with the setting back of flood embankments in order to control flood waters; the construction of flood relief channels; the sluicing of solid weirs; and local schemes for the special protection of built-up areas, including Tamworth and Long Eaton.

Of the foregoing works, the construction of the Keadby Pumping Station has now commenced, together with the regrading and resectioning of the main rivers in the area affected, whilst work on the River Idle and other rivers in the nature of regrading is in progress, together with extensive bank repairs in the tidal reach of the river between Gainsborough and Trent Falls.

The Board early decided to carry out as much work as possible by direct administration and to that end works organizations have been set up which divide the Catchment Area into three parts, namely:—

(1) The Northern Area, comprising the tidal reach of the River Trent and all main channels discharging therein.

(2) The Home Area, comprising the River Trent from Cromwell Lock to Burton-on-Trent, together with the Rivers Soar, Erewash and Derwent.

(3) The Southern Area, which includes the remainder of the main channels, including the upper reaches of the River Trent and the Rivers Dove, Tame, Cole, Anker, Sow and Penk.

The works in the Northern and Southern areas are under the direct control of Divisional Engineers, while the Home Area is directly controlled from the Head Office at Nottingham. The necessary plant for the work is considerable and comprises 15 excavators, 69 floating craft,—ranging from a large grab dredger to weeding punts,—locomotives, tips and rails, pile drivers and the like. Workshops have been constructed at Owston Ferry and Elford where all running repairs and overhauls of machinery are carried out, and where much of the plant such as hand trucks, wheel barrows, etc. are made. The labour strength totals approximately 500 men, including such tradesmen as carpenters, smiths and bricklayers.

The study of the flood relief comprehensive scheme is one of considerable difficulty and magnitude and it is realised that hydraulic formulae are far too nebulous in character to enable schemes to be prepared from calculations alone, and an important feature of the preparation of flood schemes lies in the study of working landscape models, upon
which the flood of May 1932 is reproduced. These models enable a
careful study of this flood to be made, and schemes which comprise flood
relief channels, the setting back of flood embankments and so forth can
be built on the models and all the resultant effects of such proposed works,
both above and below, can be carefully studied and connoted. The
Hydraulic Laboratory work can be said to form the foundation of the
preparation of flood alleviation schemes, and the results of this research
work have demonstrated that working models are not only helpful in
investigating flood problems, but are regarded as essential in the pre-
paration of flood alleviation schemes.

A true perspective of the possible damage caused by flooding has to
be borne in mind in the preparation of schemes. When it is pointed out
that a major flood requires a channel some 2½ times its present bank-full
capacity for flood discharge purposes, it will at once be realized that the
avoidance of all flooding in all places is outside the realms of practical
and economical considerations.

In any event, a system of wholesale enlargement of river channels
stands condemned on hydraulic grounds alone, because the normal scour-
ing velocity of the stream would be eliminated and result in a series of
rivers meandering within the enlarged river beds, and ordinary economic
maintenance works could not possibly cope with such a situation.

It is apparent, therefore, that attention must be focussed on those areas
where considerable damage can be inflicted by flood waters, such as in
built-up areas and arable lands, while controlled flooding of grass lands
would result in a minimum of damage and, in fact, improvement, pro-
viding the deposit remaining from the flood waters were free from im-
purities.

**Internal Drainage Boards**

In addition to the work of the Catchment Board on the 'main rivers'
in the Catchment Area, the jurisdiction of the Board extends over con-
siderable areas of land included within Internal Drainage Districts. An
Internal Drainage District can be described as a Drainage Area con-
stituted under the Land Drainage Act of 1861 or under any other enact-
ment relating to the drainage of land, and all Internal Drainage Districts
existing at the passing of the Land Drainage Act of 1930 are deemed to
have been constituted under the last mentioned Act. Provision is made
for the constitution of further Internal Drainage Districts by Schemes of
the Catchment Board, the principles governing the formation of such
Internal Drainage Boards applying to those Areas which will 'derive
benefit' or 'avoid danger'. Whilst there is no legal definition of these
two terms, it can be accepted that they apply generally to low land areas
which require artificial drainage works, either in respect of internal
watercourses by which the drainage of the lands derive benefit or in
respect of the embankment works of contiguous main rivers from which
damage by flood is avoided. The term 'benefit' can have a fairly wide
meaning and includes indirect benefit to a certain degree. On these
premises, therefore, it will be realised that only a minor proportion of the
Catchment Area can be considered for Internal Drainage District form-
aison, as of a total of 2,578,539 acres, only 375,000 acres can be termed low land; and as this area includes long lengths of narrow valleys which will never be formed into Internal Drainage Districts, it is obvious that the total area of all Internal Drainage Boards will never be more than a comparatively small percentage of that of the Catchment Board.

**Co-operation with Public Authorities**

A Catchment Board’s interests may easily conflict with those of other public bodies, but, on the other hand, a co-operative spirit between the parties concerned can but result in the common good.

The River Trent Catchment Board keep in close touch with the Trent Fishery Board for instance and by common consent it is agreed that dredging operations alone have improved fishing in many instances. Again, the Catchment Board maintain close co-operation with all road authorities in respect of river bridges, and whereas, in the past, bridges have been constructed both too small and too large, all plans for new structures must now be submitted to the Board, who are able to give advice on such details as spans and head rooms.

Another aspect of co-operation lies in Regional Town Planning Schemes, where the Board are in a position to advise on the sterilization of lands against buildings in cases where such lands form natural wash-lands.

**Finance**

An article on the River Trent Catchment Board, however brief, should have a reference to its source of funds. Here again the Land Drainage Act of 1930 sets out clearly the source of a Catchment Board’s revenue, namely:

(a) By precepts on County Councils and County Boroughs within the area, ordinarily limited to 2d. in the pound of rateable value.
(b) By precepts on its Internal Drainage Districts for such amounts as are considered fair and reasonable, and
(c) By Government Grants.

The River Trent Catchment Board has now stabilized its precept under (a) at 1½d. in the pound for 7 years ending 31st March 1944, while under (c) the Government have made a grant of 30 per cent for the first £1,000,000 instalment of the Comprehensive Scheme. The estimated total annual revenue from the foregoing sources is approximately £225,000 which will be sufficient to cover the cost of the first £1,000,000 of the Comprehensive Scheme together with all administrative and maintenance charges during that period. The Board’s financial policy therefore is to avoid loans, and the ultimate saving to the ratepayers of such a policy cannot be gainsaid.
ii. THE ECOLOGY OF THE RIVER TRENT AND TRIBUTARIES

BY

J. INGLIS SPICER,

CLERK AND BIOLOGIST TO THE TRENT FISHERY BOARD, NOTTINGHAM.

It may be said at the outset that practically no work has been done on the ecology of the rivers of the vast watershed of the River Trent. Indeed, such studies in this country have been very few.

Had government and local administrations made appropriate use of biological investigation, and adopted during the period of rapid industrial development and urban colonisation of the country the subsistence of fish life as the standard of purity to be maintained in the rivers, the ‘tragedy of the Trent’ would never have been written.

A little over ten years ago the Trent was justly referred to as ‘a common sewer’, and that it has escaped the fate of certain other rivers is little short of a miracle. Its rescue and partial resuscitation, laborious and slow over the past decade, goes to the credit of so-called ‘worm and bent-pin’ anglers, drawn mostly from these industries and urban colonisations which, in their inadequately planned development, were responsible for the river’s exhaustion and, at the same time, for the self-limitation of that very development.

There is inset opposite page 98 a biological diagram indicating the present situation as to river pollution in the watershed of the Trent. The diagram incorporates practically all that is known of the ecology of the rivers of the district. In the absence of definite standards ascertained by correlated biological and chemical examination the river classification must be regarded as very approximate and it is not suggested that percentage saturation of dissolved oxygen is the only factor by which extent of pollution should be assessed. The diagram shows that in this one river system there are over one hundred out of a total of five hundred and fifty miles of flowing water where neither animal nor plant life can subsist, and in little more than half of the total mileage can fish live with safety.

Industrial expansion was allowed and even encouraged to go forward without provision for the conservation of the water resources of the country. On much the same lines local authorities are to-day throughout the country throwing up vast colonies of new habitations and leaving to the indefinite future provision for the treatment of the waste products from such colonisations. Such policies could not but ultimately recoil on the promoters or their neighbours. Water-undertakers are scrambling over the hillsides over-reaching each other to tap water supplies for domestic and industrial use before the other fellow gets or contaminates
them. Existing interests snarl, and enrich the legal profession, when competitors try to tap supplies or establish polluting agencies above them in the watershed. Industrialists looking for expansion are finding that polluted watercourses prohibit development of many otherwise desirable sites.

It will be seen therefore that industrial urban expansion have set their own limits by their short-sightedness, permitted by absence of national policy. The experience of the Trent Fishery Board in its work since 1923 has clearly shown that there are few, if any, industries in which provision for the reasonable purification of their waste waters would be impracticable or even a serious charge on the industry. Any urban community should be able to provide for the adequate treatment of its waste waters on an annual expenditure of half-a-crown per head of its population out of the normal revenue of £8 per head from rates for such a community.

The root cause of the deterioration of the watercourses of the country has been that it has never been laid down in gubernatorial policy that watercourses maintained in a condition to sustain fish life would be thereby guaranteed as to general suitability for industrial, agricultural and even domestic purposes.

It will be seen at a glance from the diagram that what may be termed the persistent major pollutions in the Trent catchment are the Foulea Brook (Potteries); the River Tame Basin (Birmingham and district); the River Erewash (Derbyshire-Nottinghamshire boundary); and the River Churnet. The adverse effect of these badly polluted tributaries on the fauna and flora of the main river is apparent. The River starts off badly polluted in the Potteries and for about thirty miles not a fish and scarcely a water plant may be found. Vast improvements in sewage disposal have been made in this locality and a limited number of trade wastes are now alone responsible for the initial contamination of the river. About half way down this polluted stretch, the river receives, as a result of prehistoric sewage conditions, a serious retardant to natural recovery. Plant life begins to show itself at Haywood, and some mud fauna other than the apparently ubiquitous chironomids begin to appear. Fish life then finds itself able to subsist for a time in the main river until the River Tame and its tributaries (Birmingham district) completely depopulate the river again.

The valuable trout fishings of the River Dove and its tributaries are faced mostly by pollution from milk waste. The depopulated River Churnet offers scope for the study of the slow rehabilitation of a once badly sewage-polluted river with however, the retardant effect of effluents from dye works. That the River Derwent below Derby continues to support fish life has only been made possible by the generous acceptance of its responsibilities by a large artificial silk factory. Here a valuable study should be made of the individual effects of the effluents from (a) a group of collieries, (b) municipal sewage works, (c) a large artificial silk factory, and (d) a large power station. In the River Tame and the River Soar, the issue as to responsibility for fish mortality is too often confused by the old stand-by excuse of storm-water. River pollution from these angles calls for detailed biological investigation in situ if further progress is to be made.
A short history of the River Trent and its tributaries is worthy of consideration. The close of the nineteenth century saw the slow demise of the valuable salmon, eel and lamprey fishing industries. Evidence of what the Trent used to be as a fishing river can be deduced from the following records:

'Nottingham apprentices had a clause inserted in their indentures to the effect that they should not have Trent salmon in their dietary more often than twice a week.'

'He paid £100 a year rental for the fishing rights at the weir and could take six large salmon in one cast of his net just below Gunthorpe Bridge.'

'In one night alone—on 9th September, 1899—I caught over 70 stone of eels in my nets at Old Colwick (Nottm.).'

'At one time I had a contract to supply 40 stone of eels per week to one fishmonger but I could not guarantee to catch 40 lbs. per week now.'

'In one night at the weir he caught over 10,000 lampreys and at that time got £10 a thousand for them.'

To-day, professional eel and lamprey fishing has practically entirely disappeared, and the records of salmon takes, which at the end of the first quarter of this century had also entirely disappeared, now show an annual take of only 100 to 160 fish per season. There is little doubt that the Trent was justly named in 1925, 'a common sewer'.

How the race of Trent salmon has managed to survive, and now shows indications of rehabilitation, is a mystery to most people. As regards coarse fish, the annual reports of the Trent Fishery Board are a continuous record of fish mortality and disease attributable to preventable pollution. In 1935 some 20,000 roach and perch were killed at one blow by a discharge of municipal sewage, and in two other instances the mortality was limited to a few thousands only as a result of rescue work on suffocating fish trapped in locks, they having fled before sewage discharges. During 1936, the Trent Fishery Board supplied, from various stock ponds, about 275,000 coarse fish to replace wanton wastage.

It is satisfactory to note however, that during the past ten years the Trent has shown definite, if slow, recovery in its capacity for maintaining coarse fish life. The following selections from Press reports on angling for 1936 are of interest:

'I am glad to say that the main river (Trent) is coming back into its own again, thank goodness, after years of pollution.'

'We have had the best fishing season during 1936 for the past twenty-five years.' (Middle Trent).

'A very good fishing season—barbel now returning and roach more healthy and lively.' (Lower Trent).

'Dace appear to be steadily returning to their old haunts.' (Middle Trent).

Growing congestion in industrial communities sent the workers looking for health-giving recreation for themselves and their families, and a tremendous coarse-fish angling fraternity has made a place for itself in the national life of the country. One in ten of the insured workers in the
Trent Fishery District are licensed anglers following a recreation with apparent national advantages, quite apart from the circulation in this district alone of about one and a half million pounds per annum.

It has been said with much truth that the one effective step taken by the government to remedy river pollution was, by the Salmon and Freshwater Fisheries Act 1923, the enabling of anglers to levy a rod tax on themselves to provide funds for Fishery Boards to combat river pollution. The rescue and partial resuscitation of the River Trent, a matter of moment to industrial, agricultural and communal interests as much as to the angler, was therefore left to such financial provision as might be made by the angler. The progress made during ten years has been remarkable and the report of the Trent Fishery Board for 1936 sums up the present situation as follows:—

'It is satisfactory to be able now to record that practically all the sources of major pollution are under some control. Continuous supervision and persistent representations must, however, be maintained to preserve the ground that has been won. Assuming the non-recurrence of remedied pollution it will however take several years of natural scouring of the fouled river bed to bring about the full rehabilitation of some of the polluted streams. There are still, also, a considerable number of minor polluting agencies in the watershed with their, in total, very noxious effects. Many of these are, by reason of the fact that they do not cause immediate mortality in fish, difficult to locate and to have remedied. Further advance therefore now requires systematic analyses and biological observations conducted on a uniform basis over the whole watershed. This is, however, beyond the present financial resources of this Board.'

Such progress as has been made in the past ten years is due almost entirely to the activities of Fishery Boards whose financial resources are practically restricted to licence fees levied on anglers. In the Trent Fishery District the various county and other councils receive between them, in rates levied on occupied fishery rights, several times the total revenue of the Fishery Board but without, in most cases, any concern being shown by them for the conservation of such fisheries.

There is now a pressing need for government to bring about, or at least to facilitate, the institution of a comprehensive biological investigation of this important watershed of the River Trent. The present anomaly in regard to finance must receive consideration, but it may be noted that the cost of the required work would represent only one-twentith of a penny rate levied over the watershed. Very varying interests are to be served by the maintenance of reasonably pure rivers capable of maintaining fish life. The matter is of moment to water-undertakers, urban and rural communities, and drainage authorities. The objects to be served are the conservation of the water resources of the district to meet the growing needs of industry and domestic use, the protection of agricultural interests, the revival of valuable salmon and eel fishing industries as food producing media, and the increasing need and demand for health promoting recreation by growing urban populations.
Diagram showing Pollution and Biological Conditions observed during 1936 in the River Trent and Tributary Streams.

Approximate relationship between the Biological classification and the tested conditions of Dissolved Oxygen:

A - Over 95% D.O.
B - 80 to 90% D.O.
C - 65 to 80% D.O.
D - 50 to 65% D.O.
E - 40 to 50% D.O.
F - Under 40% D.O.

A. Conditions satisfactory for fish life generally.
B. Suitable for fish life under all normal conditions.
C. Fish life may thrive, but unable to withstand much pollution or rise of temperature.
D. Fish life may subsist, but very precariously.
E. Fish life unable to subsist - but plant life may appear.
F. Animal and plant life totally unable to subsist.
iii. THE ECONOMIC ASPECTS OF THE TRENT

BY

K. C. EDWARDS, M.A.

Day by day the River Trent plays a growing part in the commercial activity of Nottingham. The extensive works of improvement undertaken in recent years by the Trent Navigation Committee of the City Corporation, the Trent Navigation Company and the River Trent Catchment Board have embraced the modernisation of the waterway between Nottingham and Newark, the regulation of the stream, attention to its banks and the preparation of plans to alleviate the serious floods which occur from time to time.

The Trent in a special sense is Nottingham’s river, for apart from Stoke and the Potteries where the stream is of insignificant size, Nottingham is the only large city on or near its banks. Trent Bridge, too, rich in its associations of history, commerce and sport, ranks as one of the most important river-crossings in the country. Like the Thames and Severn, the Trent provides a natural waterway penetrating far inland from its tidal estuary on which navigation has been maintained to a greater or lesser degree throughout the course of history. Even in Roman times, portions of the river were used for the conveyance of grain in shallow boats, whilst later on Saxon tribes established trading connections at places along the lower reaches. The Danes appear to have made fuller use of the river as a highway and have left a record of their Trentside settlements in such names as Keadby, Althorpe, Butterwick, Gunthorpe, Bleasby and many others. Judging too, from the manner in which these Norse sailors revived the use of the ancient Fossdyke from Torksey to Lincoln, it seems that the development and organisation of the southern part of the Danclagh with its five boroughs were to some extent based upon the system of waterways provided by the Trent and its tributary connections. Then again, the river was undoubtedly an asset in fostering the Norman settlements at Newark and Nottingham, the award of fines against persons who hindered the passage of boats being mentioned in the Domesday Survey.

The Trent rose to great importance as a highway of commerce during the eighteenth century, for the beginnings of modern industry found the roads of the country hopelessly inadequate and traffic was accordingly directed to the navigable rivers wherever possible. This was an era of prosperity for a number of ‘ports’ between Burton-on-Trent and the Humber such as Nottingham, Newark, Torksey, Gainsborough and Bawtry, the last-named being on the River Idle. Gainsborough, on the tidal stretch, was accessible for sea-going vessels and became an exchange point for traffic to and from the Humber, for upstream the channel could accommodate only flat-bottomed craft and not keel vessels. The
port remained active for a long period and for some years following 1841 was registered as a seaport for the collection of customs.

During the era of the canals, the Trent served as one of the main arteries of the inland waterways of England, and locally its trade was extended by means of canals leading from Nottingham to several neighbouring centres. The Nottingham Canal itself, completed in 1802, served to connect the Erewash valley and facilitate the movement of coal. The Grantham Canal, which left the river near Trent Bridge, opened up the agricultural region of the Vale of Belvoir. There were also the Derwent and Erewash Canals. Further, in order to obviate the shallows at Wilford which have at all times been an obstruction to navigation, it was necessary to make a short lateral canal branching from the Nottingham Canal and meeting the Trent again at Beeston, whence traffic could proceed upstream to the Trent—Mersey Canal or to the Soar Navigation. The origin of the Trent Navigation Company may be traced as far back as 1783 and though not at first a transport concern, the company has steadfastly maintained for many years an active share in the trade of the river. With the coming of the railways the Trent and its connections suffered like the rest of inland waterways and trade dwindled almost to the point of stagnation. Moreover as the river fell out of use the channel became neglected and, quite apart from the inherent difficulties of low water on certain stretches in times of drought, and dangerous floods at other times, the conditions for navigation greatly deteriorated. The Royal Commission on Inland Waterways, 1906, reported the river inadequate and offering no certainty of through-carriage unhindered between Hull and either Newark or Nottingham.

Recent years nevertheless have witnessed a striking change. Trade has recovered along the whole course of the Trent from Nottingham to the Humber, and upwards of 200,000 tons of goods are moved annually on the Nottingham—Newark section alone compared with a former average of under 30,000 tons. This revival is due chiefly to post-War improvements to the channel on several stretches and to the use of modern craft fitted with a crude-oil motor which affords both a cheap and convenient means of propulsion. Just as the sail barge of olden time was superseded by the steam tug, so the latter is now largely replaced by the self-propelled ‘power barge’ as it is called. It was upon the Nottingham—Newark section that the river required most attention, for in parts the depth of the channel was not dependable and at several points the current was difficult if not dangerous. Dredging alone could not suffice owing to the gradient of the stream in this part of its course, the actual fall between Holme Pierrepont (below Trent Bridge) and Fiskerton (near Newark), a distance of 14½ miles, being 21 feet, i.e. over 17 inches per mile. Over this stretch the problem was to secure a channel with a minimum depth of 6 feet, enabling 100-ton barges to reach Nottingham at any season.

The work was begun after the War when the City Corporation, exercising its powers under an Act passed in 1915, took over from the Trent Navigation Company the control of the river from Trent Bridge to the Averham Weir close to Newark. By ‘stepping’ the river at intervals
with weirs it was possible to reduce the gradient on each of the short sections thus formed. Each weir of course was accompanied by a lock and existing locks too had to be enlarged or rebuilt in order to accommodate modern barges. By 1929 the new channel was completed and the stream thus made navigable at all times of the year from Nottingham to the sea. The ‘port’ at Nottingham, where corresponding improvements have been made, consists of two separate terminals each equipped with modern warehouses and having railway-sidings at hand. One is owned by the City Corporation and the other by the Trent Navigation Company, whose capacious up-to-date warehouse and depot was built in 1915 in anticipation of the new waterway project. In the case of the former, wharfage has been considerably extended and in 1932 a new basin and transit sheds were constructed.

The increase of traffic resulting from the modernisation of the waterway is mainly in the upstream direction and originates chiefly at Hull where the barges and river craft have direct access to ocean-going ships. The conveyance of great quantities of petroleum in special tank-barges is the outstanding feature of this trade and upon the Newark—Nottingham section this now accounts for more than 50 per cent of the total tonnage. Nottingham has in consequence become the chief distributing centre for oil in the Midlands. The expansion in river-borne trade in recent years on the Nottingham—Newark section is shown by the following figures: —

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Tonnage</th>
<th>Petrol Tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1928</td>
<td>66,960</td>
<td>4,920</td>
</tr>
<tr>
<td>1930</td>
<td>105,337</td>
<td>37,377</td>
</tr>
<tr>
<td>1932</td>
<td>284,666</td>
<td>59,206</td>
</tr>
<tr>
<td>1934</td>
<td>242,853</td>
<td>95,123</td>
</tr>
<tr>
<td>1936</td>
<td>230,514</td>
<td>117,449</td>
</tr>
</tbody>
</table>

Other bulky non-perishable commodities are timber, strawboards, cement, grain, cattle-cake and tinned foodstuffs. Downstream traffic is slight and much less regular and consists mostly of manufactured goods, e.g. hardware and machinery and occasional loads of iron pipes. Coal finds no place in the river trade for its shipment has long been in the unchallenged hands of the railways. On the other hand, the importance of the Trent is now exerting some influence at least upon the trend of commercial development not only in Nottingham but at the smaller towns of Newark and Gainsborough and at newer centres such as Keadby.
V.

SCIENTISTS OF NOTTINGHAM AND DISTRICT

BY


Of the following scientific men who, during the course of the past 300 years, have materially contributed to the advancement of scientific knowledge, the majority were born in one or other of the counties Nottinghamshire, Derbyshire and Lincolnshire. The rest either had close family connections with, or were long resident in the district.

Abney, Sir Wm. De Wiveleslie, C.B., Kt., F.R.S. (1843-1920), b. Derby. His scientific work was mainly connected with photographic chemistry and colour printing. Elected F.R.S. in 1876, he was president of the Royal Astronomical Society and of the Physical Society. Assistant secretary to the Board of Education (1899), he was adviser to its science department. He was a member of the Advisory Council for Education to the War Office (1903). C.B., 1876; Kt. 1904. He had a long and eminent connection with the British Association.

Arderne, John (?). He was the first Englishman to show much skill in surgery, and he practised in the time of Edward III. It is not known where he was born or died, but he records in one of his own manuscripts that he lived at Newark from 1349 to 1370. He wrote on surgery and what was then known of medicine, and his reputation is said to have been great for at least two centuries.

Arkwright, Sir Richard (1732-1792), b. Preston, Lancs. He worked in early life as a barber, but with the gradual disuse of wigs turned to invention. He began work on the design of a spinning frame about 1767, and settled at Nottingham in 1768 where he erected his first spinning mill. He entered into partnership with Jedidiah Strutt (q.v.) and Samuel Need and established a larger factory at Cromford, Derbyshire in 1771. He was long involved in litigation with rival manufacturers who contested his patents, and encountered opposition from workpeople who were alarmed by his labour-saving machinery. He was knighted in 1786. d. Cromford.

Banks, Sir Joseph, F.R.S. (1743-1820), b. London, son of Wm. Banks of Revesby Abbey, Lincolnshire. Educated at Harrow, Eton and Oxford, he soon became outstanding for his attainments in botany and natural history. He accompanied Captain Cook in the Endeavour on his voyage of exploration in the Antipodes (1768-71) and made many important
observations. He was President of the Royal Society from 1778 till his death, and it is recorded that he reformed several abuses of administration during his term of office. d. Isleworth.

Bigsby, John J. M.D., F.R.S. (1792-1881), b. Nottingham. He studied medicine at Edinburgh and, joining the army as a medical officer was ultimately sent to Canada where he developed so great an interest and skill in geology that he was commissioned to report on the geology of Upper Canada. In 1827 he settled in practice at Newark. He was elected F.R.S. in 1869, and in 1877 he presented the Geological Society with money to provide the Bigsby Medal to be awarded biennially to students of American geology. d. London.

Brindley, James (1716-1772). One of the earliest of English engineers, he was born in Derbyshire, the son of a small farmer. The Wedgwoods employed him to construct flint mills for grinding calcined flint used in glazing pottery. His reputation as an engineer was based on his association with the Duke of Bridgewater for whom he built over 350 miles of canals, all pioneer work in the development of inland water transport in this country.

Brown, Adrian J., F.R.S. (1867-1919). He spent the early years of his life at Burton-on-Trent. Trained as a chemist under Frankland at the Royal College of Chemistry, he was appointed in 1874 as chemist to Salt & Co., Brewers, Burton-on-Trent, and subsequently directed the department of fermentation at Birmingham University. He published a number of important papers on fermentation and hydrolysis.

Burton, F. M. (1829-1912). Well known as an all-round naturalist, a fellow of the Linnaean and Geological Societies, Burton lived in Lincolnshire most of his life, and from 1859 was at Gainsborough. The author of many papers dealing with Lincolnshire geology, he was the discoverer of the Rhaetic beds at Gainsborough, a discovery which he announced at the Nottingham Meeting of the British Association in 1866. He was president of the Lincolnshire Naturalists' Union.

Cartwright, Rev. Edmund, D.D. (1793-1823), b. Marnham, Notts. Educated at Oxford, he was rector of Goadby Marwood in Leicestershire (1779-1808). In 1785 he took out a patent for his first invention, a power hand loom. He later invented a wool combing machine and practically ruined himself trying to develop the use of these two inventions. In 1809 a timely vote of £10,000 from the Exchequer made him independent and he spent the rest of his life farming and inventing new machines. d. Hastings.

Cordeaux, John (1831-1899), b. Foston Rectory, Leicestershire. In 1860 he settled at Great Coles, Lincolnshire, and earned a reputation as Lincolnshire's most widely known naturalist. He specialised in ornithology and took a leading part in the British Association enquiry, instituted in 1880, into the subject of bird migration as observed on the coasts of Great Britain and Ireland. He was president of the Yorkshire and Lincolnshire Naturalists' Unions, and among his publications on ornithology was a book on Birds of the Humber District (1872).
Darwin, Erasmus, M.D., F.R.S. (1731-1802). The grandfather of Chas. Darwin, he was born at Elston Hall, Notts. He was educated at Chesterfield and Cambridge and studied medicine at Edinburgh. Failing to set up a practice at Nottingham he moved to Lichfield, where he prospered, and later to Derby. He founded the Philosophical Society at Derby (1784) and his publications included Zoonomia or the Laws of Organic Life (1794-6), and Phytologia or the Philosophy of Agriculture and Gardening. He had a fertile mind and a wide range of interests including botany, mechanics and sanitation. His third son, Robert Waring (father of Charles) was a successful physician and was also an F.R.S. Erasmus died at Breadsall Priory, Derby.

Deering, Charles, M.D. (1695-1749), b. Saxony. Graduating at Leyden he practised for some years in Belford, London and Rochester, and in 1736 settled in Nottingham, where he remained till his death. A pioneer botanist in Nottinghamshire, he produced a Catalogue containing some 840 entries and from which were taken most of the references to Nottinghamshire plants in botanical works published in the latter half of the eighteenth century. He assisted Dillenius, the then Sherardian professor at Oxford, to compile his Historia Muscorum.

Dudley, Dr. Harold W., O.B.E., F.R.S. (1887-1935), b. Derby. Educated at Truro College, King Edward VI Grammar School, Morpeth, and Leeds University. He worked on anti-gas research during the Great War, and afterwards became head of the department of biochemistry at the Lister Institute. He worked on the active principle of the posterior lobe of the pituitary body. He held the office of secretary of the Biochemical Society from 1922 to 1924. d. London.

Flinders, Matthew (1774-1814), b. Donington, Nr. Boston, Lincs. From 1795 to 1803 he explored the coast-line of Australia. He had great natural gifts as a surveyor and became one of the best hydrographers in the history of the navy. His original surveys of large parts of the Australian coast form the basis of modern charts. He was one of the first to investigate errors of the compass due to iron in ships. d. London.

Franklin, Sir John, F.R.S. (1786-1847), b. Spilsby, Lincs. He assisted Matthew Flinders (q.v.) in his observations in the South Pacific and began his career as an Arctic explorer in 1818. In 1819 he traversed North America from Fort York to the mouth of the Coppermine and returned through the Barren Lands barely escaping with his life. Shortly afterwards he was elected F.R.S., and the account of his expedition is one of the most classic of travel books. He led a second expedition to North America (1825-27) and after a period at home and in Australia he set out on his last expedition to the Arctic (1845) on which he and the whole party were lost. He has been credited with the discovery of the North West Passage.

Frobisher, Sir Martin (1535-1594), b. Altofts, Yorks. An explorer of great fame, he was given an estate at Finningley, North Notts., in recognition of his great national services as a pioneer in navigation. On his search for the North West Passage (1577) he was accompanied by
Edward Fenton (d. 1603) who was born at Sturton-le-Steeple, Notts., and who later (1582) commanded a small fleet sent out on a similar quest.

Gilbert, Sir Joseph H., D.Sc., F.R.S. (1817-1901), b. Hull. He was the son of the minister of Friar Lane Chapel, Nottingham, where he spent his boyhood. Trained at Glasgow as an analytical chemist, he worked for a time at University College, London. He was associated for 57 years (1843-1900) with Sir John Lawes in agricultural experiments at Rothamsted which Lawes had established as the first agricultural experimental station in the world. He was elected F.R.S. in 1860, and was Professor of Rural Economy at Oxford for 6 years (1884-1890). d. Harpenden.

Greatorex, Thomas, F.R.S. (1758-1831), b. near Chesterfield, Derby. He was organist and choirmaster of Carlisle Cathedral (1780-84) and later of Westminster Abbey (1819-31). He spent most of his time studying science and was elected F.R.S. for discovering a new way of measuring the altitude of mountains. d. Hampton.

Green, George (1793-1841), b. Sneinton, now a part of Nottingham. The windmill in which probably he and certainly his father worked still stands and, thanks to the beneficence of Mr. O. W. Hind, has been preserved as a memorial to Green. He graduated B.A. at Cambridge in 1837 and was elected to a fellowship in 1839. He has been described as 'a mathematician who stood head and shoulders above all his companions in and outside the University'.

Hall, Marshall, M.D., F.R.S. (1790-1857), b. Basford Hall, Notts. Educated at Edinburgh and abroad, he practised as a doctor in Nottingham for 8 years and then in London where he specialised in nervous diseases. One of his most important discoveries was that of reflex action. Though his theories in physiology met with opposition from the Royal Society, he was admitted as a Fellow in 1832. He published numerous scientific and medical works and devised a method of artificial respiration. d. Brighton, buried Nottingham.

Hargreaves, James (1718-1788), b. Blackburn. In 1764 he invented the spinning jenny and four years later settled in Nottingham where he established a cotton mill, possibly the first of its kind, in Wollaton Street. Like Arkwright (q.v.) he suffered attacks from hand spinners who burnt his house, destroyed his machines and forced him to leave the district.

Hawkesley, Thomas (1807-1893), b. Arnold, near Nottingham. Educated at Nottingham Grammar School and self-taught in mathematics, chemistry and geology, he was articled as an architect and became an engineer concerned mainly with water, gas and drainage. He settled in London in 1852 and remained water engineer for Nottingham where he instituted the first constant supply.

Heathcoat, John (1783-1861), b. Duffield, near Derby. Apprenticed to a hosiery maker at Long Whatton, Leicestershire, he later acquired a machinery business at Nottingham. In 1803 he removed to Hathern where he invented a lace machine which had the reputation of being the most complicated machine ever produced. He later moved to Lough-
borough where he made many improved models of his machines most of which were destroyed during the Luddite Riots (1816). This drove him to Tiverton in Devon, where he settled peacefully and where he died. Among his many other inventions was a self-narrowing stocking-frame.

HERON, SIR ROBERT (1765-1854), b. Newark. A Whig politician, he sat in parliament from 1812-1847. He was a keen student of natural history and he maintained a collection of curious animals known locally as his menagerie. His observations especially on peacocks, were often quoted by Darwin. His notes on natural history were published posthumously together with notes on politics and social economy. d. Stubton Hall, Lincs.

HIND, HENRY Y. (1823-1908), b. Nottingham. With his cousin John R. Hind (below) he was educated privately till he was fourteen. After a short period abroad and at Cambridge he went to Canada and in 1853 became professor of chemistry and geology at Trinity University, Toronto. He was frequently engaged by the Canadian Government for important surveys including the river system of Labrador, the geology of New Brunswick and the goldfields of Nova Scotia. He was the discoverer of the enormous cod banks off the Labrador coast above the straits of Belle Isle, and he charted the movements of cod and other fishes. d. Windsor, Nova Scotia.

HIND, JOHN R., F.R.S. (1823-1895), b. Nottingham. At the age of twelve he began to observe the stars, and at sixteen he began to write articles about them in the Nottingham Journal. He entered the Royal Observatory, Greenwich in 1840, and from 1844 till the time of his death was Director of the Observatory founded by George Bishop in Regent's Park and later removed to Twickenham. He superintended the Nautical Almanac from 1853-1891. He was elected F.R.S. in 1863 and was President of the Royal Astronomical Society in 1880. His publications on astronomy were numerous. d. Twickenham.

HOBSON, ERNEST WM., F.R.S. (1856-1933), b. Derby. Educated first at Derby School and then at the Royal College of Science, London, Hobson went into residence at Christ's College, Cambridge in 1874 and in 1878 was Senior Wrangler. In 1883 he was made one of the first University lecturers in mathematics, and from 1910 till 1931 he was Sadleirian professor. Elected F.R.S. in 1893 he served twice on the Council, and he was also President of the London Mathematical Society. Of his five books, all published after he was 50, his greatest was Theory of Functions of a Real Variable, which introduced to English readers the modern theories of measure and integration, and has been described as probably the most important book written by a modern mathematician.

HOLDER, REV. WM., F.R.S. (1616-1698), b. Nottingham. Having taken a degree at Cambridge, he obtained the rectory at Bletchington, Oxford, and was later collated to Ely Cathedral. He made a name for himself by teaching a deaf mute to speak and mainly as a result of this he was elected F.R.S. in 1663. Subsequent to his famous experiment he wrote
widely on deafness and speech. He was a brother-in-law of Sir Christopher Wren in whose education he had a considerable share. d. Hertford.

JOHNSON, MAURICE (1688-1755), b. Ayscoughfee Hall, Spalding. Admitted to the Inner Temple in 1705, he was called to the bar in 1710 but lived chiefly at Spalding engaged in antiquarian pursuits. He founded literary societies at Spalding (1709) and Stamford (1721), and the revival of the Society of Antiquaries, London (1717) was largely due to his efforts. He read numerous papers before the Society from 1721-1755 and was Honorary Librarian for a time.

JOHNSON, THOMAS (1600-1644), b. Yorkshire. He spent part of his youth in Lincolnshire, and returned to it to make botanical surveys. An apothecary in London, he was also a botanist of note, his reputation being made by 'a very much enlarged edition of Gerard's Herball', and Mercurius Botanicus. The latter with several lesser works comprised what is regarded as the first British Flora, and were the first English publications which described botanical journeys and listed the plants of any one well defined area.

JOWETT, THOMAS (1801-1831), b. Colwick. Though he died at an early age, Jowett, who was trained to be a doctor, did much valuable botanical work in the county. His Botanical Calendars gave localities for over a thousand plants, some of which were not previously recorded, and his herbarium, preserved in the Bromley House Library, Nottingham, contains many plants no longer to be found in the county. His co-worker GODFREY HOWITT, a Nottingham doctor, who emigrated to Australia, published, in 1839, Nottinghamshire Flora.

LEE, REV. WILLIAM (d. 1610?), b. Calverton, Notts. Educated at Cambridge, he had a charge at Calverton, where, in 1589, he invented the stocking frame. He later moved to London with his invention but, as he had little encouragement there, he was tempted across to France by Henry IV where he thrived till the King's assassination. d. Paris.

LISTER, MARTIN, F.R.S. (1636-1712), b. Radcliffe, Bucks., of Yorkshire parents. Educated privately and at St. John's College, Cambridge, Lister had close associations with Lincolnshire and lived for some time at Burwell. He was appointed second Physician in ordinary to Queen Anne. A competent zoologist, he did much pioneer work on Lincolnshire natural history. His chief work was Historia sive synopsis methodica conchyliorum.

LOWE, EDWARD J., F.R.S. (1825-1900). He lived at Highfield House, Nottingham, now the residence of the Principal of University College. He began to make meteorological observations at the age of 15 and at 21 he published A Treatise on Atmospheric Phenomena. He was also interested in astronomy and conchology, and in connection with the former he built Broadgate House, Beeston, for use as an observatory. He was one of the founders of the Royal Meteorological Society.

MIDDLETON, REV. THOS. F., F.R.S. (1769-1822), b. Kedleston, Derbyshire. The son of the rector there he was educated at Christ's Hospital and Pembroke College, Cambridge. Consecrated Bishop of Calcutta in
1814, he was the first Anglican Bishop in India, where he did much to advance education by organising schools. Before leaving England he edited *The Country Spectator* and *British Critic*. He was elected F.R.S. in 1814. d. Calcutta.

**Moysey Lewis, B.A., M.B., F.G.S. (1869-1918).** Educated at Repton School and Cambridge. Practised as medical doctor in Nottingham for many years. Was deeply interested in the Palaeontology of the Coal Measures. He devised a method of cracking ironstone nodules which enabled him to make an extensive collection of rare fossils. After soaking in water and freezing them he dropped them in boiling water. By his collections and writings he made valuable contributions to Upper Carboniferous palaeontology. At the outbreak of the War he volunteered for service and as a Captain in the R.A.M.C. he lost his life in the hospital ship 'Glenart Castle' which was torpedoed in the Bristol Channel on 26th February 1918.

**Mundella, Anthony J. (1825-1897), b. Leicester.** He settled in Nottingham, held civic offices, entered Parliament and was President of the Board of Trade in 1886 and from 1892-94. An early supporter of compulsory education he was identified with the Elementary Education Act of 1870 and the so-called Mundella Code of Education (1882). He was also active in factory, mining and other legislation.

**Newton, Sir Isaac, F.R.S. (1642-1727),** b. Woolsthorpe, near Grantham. Educated at Grantham Grammar School he showed early interest in mechanics and mathematics. Admitted to Trinity College, Cambridge, in 1661, he was elected a Fellow in 1667, and Lucasian Professor in 1672, in which year he became F.R.S. His law of universal gravitation was completed in 1685 and the first edition of *Principia* appeared in 1687. He was M.P. for Cambridge University 1689-90 and 1701-2, Warden of the Royal Mint 1694, Knighted 1705. In 1703 he was elected President of the Royal Society, an office which he held for 25 years. The second edition of *Principia* was published in 1713. His writings also included work on chemistry and theology, among other subjects. He resigned his professorship in 1701. d. Kensington.

**Percy, John, M.D., F.R.S. (1817-1889), b. Nottingham.** Educated privately, in Paris, and at Edinburgh University, where he graduated in medicine, he was elected, in 1839. physician to Queen's Hospital, Birmingham. The metallurgical works in the district aroused his interest and he studied metallurgy intensely. In 1848 he invented a method of extracting silver from ores which led to the van Patera and Russell processes. In 1851 he became lecturer in metallurgy in the Metropolitan School of Science (later Royal School of Mines) and taught most of the metallurgists of his time. In 1864 he published *Iron and Steel*, the first book of its kind, a classic in which was presented all then known about metallurgical processes. He was elected F.R.S. in 1847. d. Bayswater.

**Plumptre, Henry, M.D., F.R.S. (d. 1746), b. Nottingham.** A pensioner of Queen's College, Cambridge, of which he was later elected a Fellow, he was admitted a candidate of the Royal College of Physicians in 1708,
and, after holding several junior offices, was President from 1740 to 1745. He was physician to St. Thomas’s Hospital, and he contributed to the fifth Pharmacopoeia Londinensis which appeared in 1746. His son RUSSELL PLUMPTRE (1709-1793) was Regius Professor of Physic at Cambridge.

RANSOM, WILLIAM H., M.D., F.R.S. (1824-1907), b. Cromer, Norfolk. Educated privately and at University College, London, he was a fellow student of Huxley. He studied in Paris and in Germany, and taking his medical degree in London (1850) settled in Nottingham where, for 36 years, he was Physician to the General Hospital. He was elected F.R.S. in 1870 for his great knowledge of physiology, particularly for original observations on ovology, his candidature being supported by Huxley, Paget and Lister. His chief contributions were made to pure science in early life as he later became absorbed in professional duties. He assisted in British Association researches on Derbyshire Caves. d. Nottingham.

ROOKE, MAJOR HAYMAN, F.R.S. (d. 1806). Rooke lived near Mansfield and was a well-known meteorologist and antiquarian. He published various papers on camps and earthworks in Nottinghamshire and on Sherwood Forest.

SPENCER, HERBERT (1820-1903), b. Derby. The only surviving child of a schoolmaster, Spencer was educated partly at a day school and partly privately by his uncle. Before definitely embarking on a career of writing he was first a teacher and then a railway engineer and inventor. After a phase of newspaper and essay writing, he settled down in 1857 to write out his system of philosophy, First Principles being completed in 1862. Among his numerous books on philosophy, ethics, and science, are the following: —Principles of Psychology (1855); Education (1861) which has been translated into all the chief languages of the world; Principles of Biology, in which he had the co-operation of Huxley and Hooker.

SHIPMAN, JAMES (d. 1901). Assistant Editor of the Nottingham Daily Express, he devoted his spare time to the examination of the numerous temporary exposures of rocks made during excavations in and around the city, and accumulated much valuable local geological and archaeologi- cal information, some of which is recorded in the Transactions of the Nottingham Naturalists, The Midland Naturalist and several books. He fostered open air science by organising a rambling club.

STRUTT, EDWARD, F.R.S., 1st Baron Belper (1801-1880), b. Derby. The son of William Strutt (below), he was educated at Cambridge where he was President of the Union Society, read law and took an M.A. degree. He spent most of his leisure studying science and particularly sociology and economics. He represented Derby and Nottingham in Parliament and was in turn High Sheriff and Lord Lieutenant of Notts. He was created Baron Belper in 1856, and in 1871 was appointed President of University College, London. In middle age he was an authority on questions of free trade, law reform and education. He was elected F.R.S. in 1860, and was also a Fellow of the Geological and Zoological Societies. d. London.
STRUTT, JEDIDIAH (1726-1797), b. South Normanton, Derbyshire. He invented a ribbing machine, and joined Samuel Need, hosier, of Nottingham, in business there and at Derby. Both were associated with Arkwright (above) in the development of the cotton spinning frame and opened the first mill at Nottingham. Strutt also established mills at Belper, Milford and Derby and greatly improved the manufacture of calico.

STRUTT, WILLIAM, F.R.S. (1756-1830). Eldest son of Jedidiah Strutt (above), he inherited much of his father's mechanical genius. He worked on systems of ventilating and heating large buildings and invented the Belper stove which was the most efficient stove of its kind. He also invented a self-acting spinning mule. A close friend of Erasmus Darwin and other well-known scientists of the day, he was elected F.R.S. for his inventive genius. d. Derby.

STukeley, William, F.R.S. (1687-1765), b. Holbeach, Lincs. Educated at Holbeach Free School and Corpus Christi College, Cambridge, he studied surgery at St. Thomas's Hospital, practised for a time in Boston (1710-1717) and then moved to London. Well known as an antiquary he became F.R.S. in 1717 and, the following year, helped to found the Society of Antiquaries of which he became Secretary. In 1724 he published Itinerarium Curiosum. In 1729 he was ordained and held livings in Stamford, Somerby and London. d. London.

Tennant, James (1808-1881), b. Upton, near Southwell. When he was still a boy his family moved to Derby where he was apprenticed to a dealer in minerals whose business he later acquired. He attended lectures in London by Michael Faraday on whose recommendation he was appointed lecturer in mineralogy at King's College, London (1838). He was also lecturer in mineralogy and geology at Woolwich (1850-1867). He was appointed mineralogist to Queen Victoria in 1840 and supervised the recutting of the famous Koh-i-noor diamond. He wrote papers on fossils and precious stones. d. London.

Thoroton, Robert (1623-1678). Born of a family who had long held property in Nottinghamshire he practised as a doctor at Car Colston, but, confessing that he was unable ‘to keep people alive for any length of time’ he turned ‘to practise on the dead’. He began work in 1667 on his Antiquities of Nottinghamshire which was published ten years later and brought him a good reputation as an antiquary. d. Car Colston.

Vigani, John F. (1650-1712), b. Verona. After travelling throughout Europe acquiring a knowledge of medicine and pharmacy he came to England in 1682, married an Englishwoman and settled down at Newark. In 1683 he began to give private tuition in chemistry at Cambridge and was appointed professor (the first) in 1703. He was a skilled experimenter and a successful teacher especially in materia medica, and he made useful observations on antimony and the distillation of acetic acid. He retired to Newark where he died.

Willughby, Francis, F.R.S. (1635-1672), b. Middleton, Warwick. He belonged to the family of Willughbys of Wollaton, and took his arts
degrees at Cambridge. In 1662 he travelled with John Ray in the north Midlands assisting in the work of compiling a catalogue of British plants; and in 1663 they went abroad together to collect a complete catalogue of animals and plants. Many of Willughby's specimens are still preserved in Wollaton Hall. He was one of the original Fellows of the Royal Society (1663). After his death, at Middleton, his notes on birds, insects and fishes were published by John Ray. Willughby is considered to have been the first to treat the study of birds as a science and his classification is said to be without doubt the system on which Linnaean classification was based.

Willughby, Percivall (1596-1685), b. Wollaton Hall, Notts. The sixth son of Sir Percivall Willughby, he was educated at Rugby, Eton and Oxford, and having trained as a doctor he settled down in Derby where he acquired a very high reputation for his knowledge of and skill in obstetrics. He left manuscripts on obstetrics in English and Latin, one of which was translated into Dutch. A man of high culture and powerful intellect he was a friend of most of the scientific men of the century. d. Derby.
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